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The Association of Socioeconomic Status With Hypertension in 76 Low- and Middle-Income Countries

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ABSTRACT

BACKGROUND Effective equity-focused health policy for hypertension in low- and middle-income countries (LMICs) requires an understanding of the condition's current socioeconomic gradients and how these are likely to change in the future as countries develop economically.

OBJECTIVES This cross-sectional study aimed to determine how hypertension prevalence in LMICs varies by individuals' education and household wealth, and how these socioeconomic gradients in hypertension prevalence are associated with a country's gross domestic product (GDP) per capita.

METHODS We pooled nationally representative household survey data from 76 LMICs. We disaggregated hypertension prevalence by education and household wealth quintile, and used regression analyses to adjust for age and sex.

RESULTS We included 1,211,386 participants in the analysis. Pooling across all countries, hypertension prevalence tended to be similar between education groups and household wealth quintiles. The only world region with a clear positive association of hypertension with education or household wealth quintile was Southeast Asia. Countries with a lower GDP per capita had, on average, a more positive association of hypertension with education and household wealth quintile than countries with a higher GDP per capita, especially in rural areas and among men.

CONCLUSIONS Differences in hypertension prevalence between socioeconomic groups were generally small, with even the least educated and least wealthy groups having a substantial hypertension prevalence. Our cross-sectional interaction analyses of GDP per capita with the socioeconomic gradients of hypertension suggest that hypertension may increasingly affect adults in the lowest socioeconomic groups as LMICs develop economically.
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Hypertension is one of the most important modifiable risk factors for cardiovascular and cerebrovascular disease,[1,2] which is estimated to be the leading cause of death in low- and middle-income countries (LMICs).[3] The prevalence of hypertension is already high across many LMICs and is expected to increase further over the coming decades as populations age and lifestyles continue to change.[4] As a condition that is associated with obesity and a sedentary lifestyle,[5,6] hypertension is often thought to mainly affect wealthier individuals in LMICs. This belief likely is an important reason behind why the condition is receiving less funding from LMIC governments and donors relative to the disease burden it causes compared with many other global health issues, particularly HIV, tuberculosis, and malaria.[7,8] Nonetheless, more recently, several major programs in LMICs have been initiated to begin addressing hypertension in these settings.[9-11]

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Understanding the socioeconomic gradients associated with hypertension within LMICs, and how these may change in the future, is important for policymakers for several reasons. First, achieving equity in health requires an understanding of which health conditions are most prevalent among the most socioeconomically disadvantaged segments of society. These equity considerations are particularly important for hypertension because those of the lowest socioeconomic status in LMICs are generally least able to access high-quality health care services (or even basic health care services) for the sequelae of hypertension and are most likely to experience impoverishing health care expenditures from doing so.[12] They are also typically the population groups who are most dependent on their full health to earn a livelihood,[13] and thus—independently of health care expenditures—are at greatest risk of impoverishment when struck by cerebrovascular disease. Second, independently of equity considerations, evidence on socioeconomic gradients in hypertension prevalence may help effectively target prevention and treatment interventions to those who need them. Third, an understanding of how socioeconomic gradients in hypertension are likely to change in the future can help policymakers not only plan treatment strategies accordingly, but also counteract such changes through appropriate preventive measures.

ABBREVIATIONS AND ACRONYMS

BP = blood pressure

GDP = gross domestic product

LMIC = low- and middle-income country

Despite its importance, there is little evidence from nationally representative studies on how hypertension varies by socioeconomic status in LMICs.[14,15] Therefore, this study has 3 aims: 1) to determine the association of educational attainment and household wealth with hypertension in each of 76 LMICs; 2) to determine whether and how the relationship between socioeconomic status and hypertension differs between World Health Organization world regions; and 3) to determine how socioeconomic gradients of hypertension within countries are associated with a country's level of economic development and may, thus, change as countries continue to develop economically.

METHODS

DATA SOURCES. We conducted a systematic search to identify household survey data sets with the following characteristics: 1) conducted in a country that was an LMIC at the time of data collection (according to the World Bank income classification[16]); 2) carried out during or after 2005; 3) nationally representative for at least 2 10-year age groups above the age of 15 years; 4) response rate ≥50%; and 5) took at least 2 blood pressure (BP) measurements.

Our analysis included 76 surveys, of which 58 were World Health Organization Stepwise Approach to Surveillance (STEPS) surveys. The process of data acquisition is described in Supplemental Methods 1 and Supplemental Figures 1 and 2. Information on the sampling process and methods of each survey is provided in Supplemental Methods 2.

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DEFINING HYPERTENSION AND SOCIOECONOMIC STATUS. We defined hypertension as systolic BP ≥140 mm Hg, diastolic BP ≥90 mm Hg, or reporting to be taking medication to lower BP. The proportion of participants taking BP-lowering medication and the proportion of participants with controlled BP (defined as taking BP-lowering medication and having both a systolic BP <140 mm Hg and a diastolic BP <90 mm Hg) among all those with hypertension is shown in Supplemental Figures 3 to 6. Supplemental Methods 3 and Supplemental Table 1 provide detailed information on the computation of the hypertension variable and on the BP measurement devices used in each survey.

We used both education and household wealth as measures of socioeconomic status. Education was classified into 5 categories, but we also show all analysis results when using years of education as the measure of education in the Supplemental Appendix (Supplemental Figures 7 to 11, Supplemental Tables 2 to 5). Household wealth was measured using an asset index or data on household income in 13 and 49 countries, respectively. The computation of household wealth quintiles is described in detail in Supplemental Methods 4. In secondary analyses, we stratified the results by whether the survey allowed for an asset- or income-based household wealth index (Supplemental Figures 12 and 13, Supplemental Table 6) and by rural vs urban location (Supplemental Figures 14 to 17, Supplemental Tables 7 and 8).

STATISTICAL ANALYSIS. For all steps of the analysis, we used sampling weights at the individual level that accounted for the complex survey design. The survey designs and weighting procedures for each survey are described in more detail in Supplemental Methods 2. In regional and global analyses, we assigned each country a weight proportional to its population size in 2015.[17,18] However, we also show the regional analyses in the Supplemental Appendix with countries being weighted equally (Supplemental Figure 18).

We categorized countries into 6 regions according to the World Health Organization's regional groupings: Africa, Eastern Mediterranean, Europe, the Americas (henceforth referred to as "Latin America and the Caribbean"), Southeast Asia, and the Western Pacific. All analysis steps were conducted for each of 3 measures of socioeconomic status: household wealth quintile, educational attainment as a categorical variable, and years of education. To investigate whether the association of socioeconomic status with hypertension varied by sex, we show all analyses separately for women and men in the Supplemental Appendix. We did not adjust for body mass index (BMI) in our primary analyses because BMI may be a mediator of the association of hypertension with socioeconomic status. Our aim in this analysis, however, was to describe differences in hypertension prevalence across socioeconomic groups, regardless of whether these differences may be attributable to differences in BMI. Nevertheless, in secondary analyses, we adjusted for BMI as a continuous variable, using restricted cubic splines with 5 knots. These results are shown in the Supplemental Appendix. Three surveys were excluded from analyses in which BMI was included as independent variable: Peru (measured BMI only among women), and Egypt and Ukraine (provided no BMI data).

All analyses were complete-case analyses, performed in August 2021 and April 2022, and implemented in R version 3.5.2 (R Foundation for Statistical Computing). Our objective was to describe patterns rather than formal hypothesis testing. As such, we have not adjusted *P* values or 95% CIs for multiple hypothesis testing.

Our analysis was conducted in 3 steps. First, to examine the association between socioeconomic status and hypertension across our sample of LMICs and how this association varies by region, we regressed hypertension onto 1 measure of socioeconomic status, sex, and age separately for each region. To allow for nonlinearities in age, we used restricted cubic splines with 5 knots (placed at the fifth, 27.5th, 50th, 72.5th, and 95th percentiles). All regression models were Poisson regressions with a robust error structure. Standard errors were adjusted for clustering at the level of the primary sampling unit in all surveys except for the surveys in the Seychelles, Grenada, Romania, Marshall Islands, and Niger, for which we did not have information on the primary sampling unit and for which we, thus, adjusted for clustering at the country level. To improve comparability between regions (given that the age range sampled in each survey differed between countries), we restricted the sample for these regressions to those aged 25 to 49 years in secondary analyses shown in the Supplemental Appendix and when plotting average-adjusted predictions. We chose this age range because it was sampled in all surveys except for Peru (which was excluded from these analyses), as well as Namibia (which was included but did not sample participants between the age of 25 to 35 years).

Second, to examine how the association between socioeconomic status and hypertension varies among countries, we ran the same regressions as in the first analysis step separately for each country, and then plotted the average adjusted prediction of hypertension for each education category and household wealth quintile. To investigate the heterogeneity of hypertension prevalence across countries and regions, we calculated the proportions of the total variance that can be attributed to country or region from a linear regression that regressed hypertension onto the measure of socioeconomic status as an individual-level predictor, and a random intercept for either country or region.

Third, to examine whether and how the association between socioeconomic status and hypertension may change as LMICs continue to develop economically, we fitted multilevel models. These models regressed hypertension onto 1 measure of socioeconomic status, age (again using restricted cubic splines with 5 knots), sex, a random intercept for country, each country's gross domestic product (GDP) per capita, and an interaction term between GDP per capita and the measure of socioeconomic status. To improve computation and interpretation of the coefficients, we grand-mean centered GDP per capita and age, and scaled these variables by subtracting the mean and dividing by 2 SDs. We used data from the World Bank on GDP per capita in constant 2011 purchasing-power-parity-adjusted dollars for the year in which the survey of each country was conducted.[19]

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 May 9, 2018.

INFORMED CONSENT OF STUDY PARTICIPANTS. Written informed consent was obtained from participants before administration of the questionnaire.

RESULTS

SAMPLE CHARACTERISTICS. A total of 1,251,710 individuals from 76 countries participated in the surveys of whom 40,324 (3.2%) had no information about whether they were using BP-lowering medication or had missing values for BP measurements, and were therefore excluded from the analysis. The sample for analysis was, thus, 1,211,386 participants of whom 237,849 (19.6%) had hypertension. The survey-level median age was 40 years, and a survey-level median of 58.5% of participants were women (**Table 1**). Differences in the sample characteristics between the sample for analysis and individuals who were excluded caused by missing information to define hypertension are shown in Supplemental Tables 9 and 10. Sample sizes by country, education, and household wealth quintile are shown in Supplemental Tables 11 and 12. Examining the proportion of participants with hypertension who were taking BP-lowering medication, we found that treatment rates among individuals with hypertension increased with GDP per capita of a country, with women having generally higher rates of taking medication. There was no clear trend of treatment rates by educational attainment, whereas we found higher proportions of individuals with hypertension reporting to be taking BP-lowering medication in higher household wealth quintiles in some countries (Supplemental Figures 3 and 4). We found similar trends when examining the proportion of participants with hypertension whose BP was controlled. (Supplemental Figures 5 and 6).

ASSOCIATION BETWEEN SOCIOECONOMIC STATUS AND HYPERTENSION BY REGION. Across the 6 regions studied, the socioeconomic gradient associated with hypertension tended to be relatively flat (**Central Illustration,** Supplemental Table 13). In most of the regions, there was no clear association of either education or household wealth quintile with hypertension, with some notable exceptions (**Table 2,** Supplemental Table 14). Specifically, there was a comparatively strong positive association of household wealth quintile with hypertension in Southeast Asia (risk ratio [RR] for wealthiest vs least wealthy quintile: 1.28 [95% CI: 1.22-1.34]). Education was positively associated with hypertension in Southeast Asia and negatively in the Eastern Mediterranean region (RRs for "more than high school" vs "no formal schooling" of 1.25 [95% CI: 1.20-1.31] and 0.87 [95% CI: 0.82-0.92], respectively). The gradient of these associations tended to be steeper among men than among women (Supplemental Tables 15 and 16, Supplemental Figure 19).

Even in regions with comparatively strong positive associations of socioeconomic status with hypertension on a relative scale, the absolute differences between education groups and household wealth quintiles were small. For instance, the average marginal effect between the most and least educated group and the highest and lowest household wealth quintile was 0.9 percentage points (95% CI: 0.7-1.1 points) and 4.3 percentage points (95% CI: 3.5-5.1 points) in Southeast Asia, respectively.

After adjusting for BMI, the absolute differences in hypertension prevalence between socioeconomic groups remained small (Supplemental Figures 20 and 21, Supplemental Table 17). The average adjusted predictions of hypertension for each region by sex, urban or rural location, the "130/80" BP threshold and the use of different BP measurements to define

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TABLE 1 Survey Characteristics by World Region[a]

Country	Year of Survey	Response Rate[b]	Sample Size	Age Range, y	Median Age, y	Female, %	Hypertension, % (n)	Missing Outcome,[c] %	Population In 2015, Thousands	GDP per Capita in 2015, $PPP
Africa										
Algeria	2016	93.0	6,789	18-69	40.0	56.0	28.8 (1,955)	2.9	39,728	13,940
Benin	2015	97.9	5,080	18-69	35.0	54.7	32.4 (1,648)	0.9	10,576	1,987
Botswana	2014	63.0	4,004	15-69	34.0	67.6	34.6 (1,387)	1.6	2,121	16,175
Burkina Faso	2013	97.8	3,993	25-64	36.0	53.9	17.9 (713)	15.1	18,111	1,562
Cabo Verde	2007	99.4	1,756	25-64	41.0	62.2	42.4 (745)	0.2	525	5,317
Comoros	2011	96.5	5,378	25-64	38.5	71.2	26.8 (1,440)	1.5	777	2,465
Eritrea	2010	97.0	6,234	25-74	42.0	72.5	16.3 (1,015)	0.5	3,343	1,485
Eswatini	2014	81.8	3,180	15-70	33.0	65.1	29.7 (945)	9.9	1,104	7,871
Gambia	2010	77.9	3,821	25-64	35.0	57.0	27.7 (1,060)	6.9	2,086	2,435
Ghana	2007/2008	79.4	4,967	18-114	60.0	46.9	52.6 (2,614)	2.8	27,849	2,760
Kenya	2015	95.0	4,401	18-69	35.0	60.2	26.8 (1,181)	1.6	47,878	2,836
Lesotho	2012	80.0	2,232	25-64	42.0	66.7	41.3 (922)	3.4	2,059	2,677
Liberia	2011	87.1	1,835	24-64	34.0	55.4	26.9 (494)	2.0	4,472	1,139
Malawi	2009	95.5	3,906	25-64	37.0	69.7	34.7 (1,355)	25.0	16,745	1,038
Mozambique	2005	98.3	3,069	25-64	38.0	58.4	35.8 (1,098)	7.1	27,042	742
Namibia	2013	96.9	3,613	35-64	46.0	57.6	42.6 (1,540)	17.9	2,315	9,256
Niger	2007	91.3	2,746	15-64	36.0	47.6	37.0 (1,016)	0.4	20,002	961
Rwanda	2012	98.8	7,115	15-64	33.0	62.8	19.3 (1,376)	1.5	11,369	1,489
STP	2009	95.0	2,443	25-64	37.0	57.2	39.8 (972)	0.6	199	2,734
Seychelles	2013	73.0	1,239	25-64	47.0	57.2	33.3 (412)	0.1	95	23,540
Sierra Leone	2009	90.0	4,825	25-64	37.0	54.2	34.4 (1,660)	3.4	7,172	1,088
South Africa	2016	83.1	8,099	15-95	36.0	60.3	46.6 (3,772)	19.9	55,386	12,253
Tanzania	2012	94.7	5,512	25-64	40.0	53.8	31.1 (1,712)	1.6	51,483	2,228
Togo	2010	91.0	4,127	15-64	32.0	51.9	20.5 (844)	5.2	7,323	1,242
Uganda	2014	99.0	3,893	18-69	33.0	59.7	25.0 (972)	2.4	38,225	1,637
Zambia	2017	74.0	4,152	18-69	34.0	62.6	22.0 (914)	3.5	15,879	3,485
Zanzibar	2011	91.0	2,452	24-64	40.0	61.4	34.2 (838)	1.4	1,441	651
Total for Africa	–	92.2[d]	110,861[e]	–	37.0[d]	58.4[d]	32.4[d] (34,600[e])	2.4[d]	415,305[e]	–
Eastern Mediterranean										
Egypt	2015	95.0	14,788	15-59	33.0	53.0	16.7 (2,475)	0.5	92,443	10,097
Iran	2016	98.4	29,859	18-100	42.0	52.4	25.8 (7,693)	2.2	78,492	18,664
Iraq	2015	98.6	3,339	18-108	42.0	62.8	46.7 (1,560)	17.8	35,572	14,964
Lebanon	2017	67.0	1,748	16-69	47.0	57.8	35.3 (617)	8.0	6,533	11,647
Libya	2009	73.0	3,353	25-64	40.0	49.9	37.2 (1,246)	6.6	6,418	28,430
Morocco	2017	89.0	5,397	18-100	44.0	65.2	32.2 (1,737)	0.6	34,664	3,036
Sudan	2016	95.0	7,648	18-69	36.0	65.1	36.7 (2,804)	1.0	38,903	4,357
Total for Eastern Mediterranean	–	95.0[d]	66,132[e]	–	42.0[d]	57.8[d]	35.3[d] (18,132[e])	2.2[d]	293,025[e]	–
Europe										
Albania	2008	95.4	6,379	15-49	33.0	55.2	23.4 (1,493)	4.3	2,891	9,154
Azerbaijan	2017	97.0	2,787	18-69	47.0	59.4	38.7 (1,078)	0.5	9,623	15,929
Belarus	2016	87.1	5,002	18-69	48.0	58.3	51.7 (2,585)	0.2	9,439	16,763
Georgia	2016	75.7	4,019	18-69	50.0	70.5	44.5 (1,788)	4.4	4,024	9,277
Kazakhstan	2012	93.0	10,883	15-90	43.0	57.3	27.4 (2,987)	13.9	17,572	21,986
Kyrgyzstan	2013	100.0	2,609	25-64	44.0	64.0	49.9 (1,302)	0.5	5,959	3,117
Moldova	2013	83.5	4,569	18-69	48.0	62.4	49.5 (2,261)	5.0	4,071	5,436
Romania	2015/2016	69.1	1,970	18-80	47.0	52.5	49.6 (978)	0.0	19,925	21,224
Russia	2007/2008	61.4	4,191	18-100	62.0	64.1	63.9 (2,679)	3.8	144,985	23,403
Tajikistan	2016	94.0	2,696	18-70	39.0	59.5	45.5 (1,227)	0.8	8,454	2,785
Ukraine	2007	81.5	7,898	15-49	33.0	68.4	25.1 (1,979)	18.3	44,922	8,497
Total for Europe	–	87.1[d]	53,003[e]	–	47.0[d]	59.5[d]	45.5[d] (20,357[e])	3.8[d]	271,865[e]	–

Continued on the next page

TABLE 1 Continued

Country	Year of Survey	Response Rate[b]	Sample Size	Age Range, y	Median Age, y	Female, %	Hypertension, % (n)	Missing Outcome,[c] %	Population In 2015, Thousands	GDP per Capita in 2015, $PPP
Latin America and the Caribbean										
Belize	2005/2006	92.6	2,429	19-97	44.0	58.9	28.5 (693)	0.2	361	7,940
Brazil	2013	86.0	57,394	18-101	41.0	56.5	30.5 (17,495)	10.8	204,472	15,433
Chile	2009/2010	85.0	4,848	15-100	46.0	59.8	30.8 (1,494)	8.4	17,969	18,995
Costa Rica	2010	87.8	3,445	18-110	47.0	72.1	36.1 (1,244)	5.0	4,848	13,000
Ecuador	2018	69.4	4,536	18-69	40.0	58.1	19.9 (901)	2.2	16,212	10,322
Grenada	2009-2011	67.8	1,097	24-64	44.0	59.9	41.9 (460)	2.8	110	11,135
Guyana	2016	66.7	2,631	18-69	40.0	59.9	29.2 (767)	0.9	767	7,266
Mexico	2009-2012	90.0	20,938	15-99	35.0	56.6	24.2 (5,058)	30.2	121,858	15,837
Peru	2012	94.4	29,412	40-96	54.0	52.6	26.4 (7,771)	5.3	30,471	10,944
SVG	2013	67.8	3,450	18-69	42.0	56.0	30.5 (1,053)	1.6	109	10,194
Total for Latin America and the Caribbean	–	85.5[d]	130,180[e]	–	43.0[d]	58.5[d]	29.9[d] (36,936[e])	3.9[d]	397,177[e]	–
Southeast Asia										
Bangladesh	2018	93.3	8,147	18-69	38.0	53.6	25.3 (2,060)	0.5	156,256	2,571
Bhutan	2014	96.9	2,803	18-69	39.0	62.0	39.3 (1,101)	0.3	728	7,366
India	2015/2016	96.0	742,618	15-54	30.0	85.6	13.2 (98,297)	2.0	1,310,152	5,927
Indonesia	2014	83.0	32,469	15-110	35.0	53.2	24.2 (7,859)	0.7	258,383	10,003
Myanmar	2014	91.0	7,983	25-64	45.0	65.4	35.0 (2,797)	3.5	52,681	4,246
Nepal	2019	86.4	5,580	15-69	38.0	64.2	29.3 (1,636)	0.2	27,015	2,164
Sri Lanka	2014	72.0	4,931	18-69	44.0	61.4	32.8 (1,617)	5.0	20,908	11,257
Timor-Leste	2014	96.3	2,565	18-69	40.0	58.6	27.7 (710)	1.7	1,196	6,263
Total for Southeast Asia	–	95.5[d]	807,096[e]	–	38.5[d]	61.7[d]	28.5[d] (116,077[e])	1.2[d]	1,827,319[e]	–
Western Pacific										
Cambodia	2010	94.2	5,313	25-64	43.0	64.6	14.5 (771)	2.2	15,521	2,522
China	2009	88.0	9,741	15-99	50.1	52.4	29.1 (2,832)	9.3	1,406,848	8,652
Kiribati	2015	55.0	1,280	18-69	37.0	55.9	35.4 (453)	40.6	111	2,107
Laos	2013	99.2	2,535	16-65	38.0	60.5	17.4 (441)	0.3	6,741	5,874
Marshall Islands	2017	92.3	2,865	17-86	37.0	53.1	19.7 (563)	4.7	57	3,706
Mongolia	2013	95.0	5,985	15-64	33.0	54.8	27.1 (1,623)	0.5	2,998	7,368
Samoa	2013	64.0	1,550	18-64	39.0	61.0	22.6 (351)	12.2	194	5,506
Solomon Islands	2015	58.4	1,877	18-69	39.0	55.4	24.1 (452)	25.7	603	2,446
Tokelau	2014	70.0	545	18-64	39.0	53.0	29.9 (163)	1.6	1	613
Tonga	2017	85.7	3,727	18-69	40.0	64.9	39.4 (1,470)	3.4	101	6,467
Tuvalu	2015	76.0	1,089	18-69	41.0	54.0	48.0 (523)	5.7	11	3,614
Vanuatu	2011	94.0	4,533	25-64	40.0	49.7	29.8 (1,352)	2.4	271	2,906
Vietnam	2015	64.1	3,074	18-69	44.0	57.2	24.5 (753)	18.2	92,677	6,103
Total for Western Pacific	–	85.7[d]	44,114[e]	–	39.0[d]	55.4[d]	27.1[d] (11,747[e])	4.7[d]	1,526,134[e]	–
Total	–	90.5[f]	1,211,386[g]	–	40.0[f]	58.5[f]	30.5[f] (237,849[g])	2.6[f]	4,730,825[g]	–

[a]All values are unweighted. Weighted prevalences of hypertension are shown in Supplemental Table 28. [b]Response rate includes both the individual and the household response rate. For Peru, this is the response rate among women because the men's response rate was not available. For China, this is the response rate for the most recent wave of the survey for which a response rate was published (2006). [c]This is the percent of participants with a missing response for use of blood pressure–lowering medication or for the blood pressure measurement. [d]This is the median across all countries in the respective region. [e]This is the sum across all countries in the respective region. [f]This is the median across all countries. [g]This is the sum across all countries.

$PPP = constant 2011 purchasing-power-parity-adjusted dollars; STP = Sao Tome and Principe; SVG = St. Vincent and the Grenadines

hypertension, and by 10-year age group are shown in Supplemental Figures 14, 19, and 22 to 25.

ASSOCIATION OF SOCIOECONOMIC STATUS WITH HYPERTENSION BY COUNTRY. There was a wide degree of heterogeneity in the association between socioeconomic status and hypertension among countries within a region (**Figure 1,** Supplemental Figure 26, Supplemental Tables 18 and 19). For instance, although the association between level of education and hypertension was positive in Peru, it was negative in Brazil. Similarly, there was a strong positive association between education and

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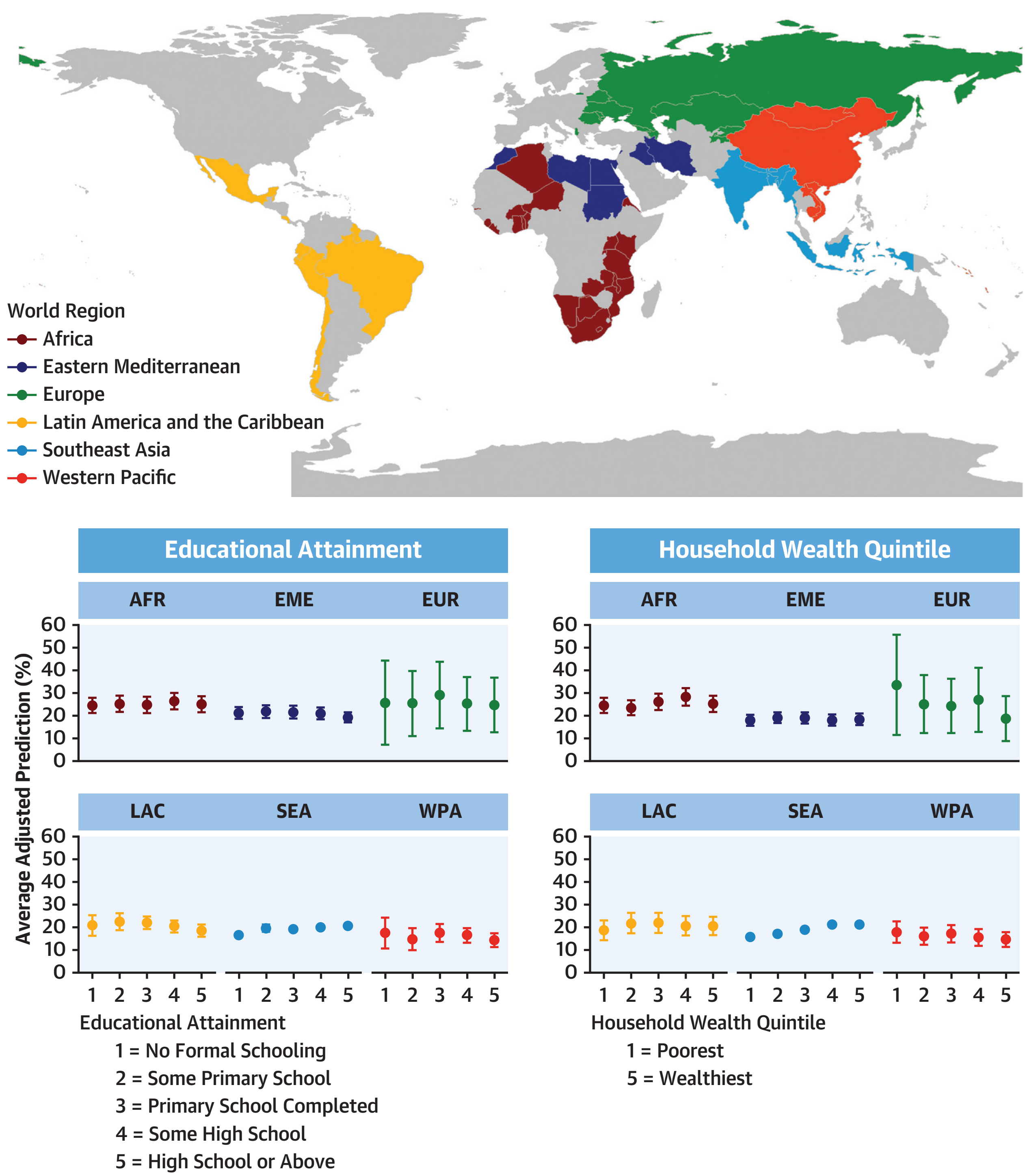
CENTRAL ILLUSTRATION **Average Adjusted Prediction of Hypertension by Socioeconomic Status**



Kirschbaum TK, et al. J Am Coll Cardiol. 2022;80(8):804–817.

Average adjusted predictions were obtained from a Poisson regression, fit separately for each region, of hypertension onto either educational attainment or household wealth quintile as categorical variables, age as a continuous variable, sex as a dichotomous variable, and a binary indicator variable for each country. We calculated average adjusted predictions based on average marginal effects for each household wealth quintile or level of educational attainment for each region. We show results for the age group 25 to 49 years. **Error bars** depict the 95% CIs. AFR = Africa; EME = Eastern Mediterranean; EUR = Europe; LAC = Latin America and the Caribbean; SEA = Southeast Asia; WPA = Western Pacific.

hypertension in Bangladesh, whereas the same associations were much weaker in neighboring India and Nepal. The magnitude of the differences in the average adjusted prediction of hypertension between the lowest and highest category exceeded 10 percentage points in 13 of 76 countries for educational attainment and in 10 of 62 countries for household wealth quintile. There was also some heterogeneity in these associations by sex (Supplemental Figures 27 and 28). The *P* values for a test of linear trend and an F-test of the null hypothesis that all education groups or household wealth quintiles in a country have the same risk of hypertension are shown in Supplemental Table 20. Defining hypertension according to the American College of Cardiology/American Heart Association 2017 guidelines increased hypertension prevalence, but did not substantially change the patterns of the association of socioeconomic status with hypertension (Supplemental Figure 29, Supplemental Tables 21 and 22). Similarly, the results did not change substantially when using different BP measurements for defining hypertension (Supplemental Figure 30). Hypertension prevalence by educational attainment and household wealth quintile in each country is shown in Supplemental Figure 31. Average adjusted predictions of hypertension by years of completed education are shown in Supplemental Figure 8.

The percentage of the total variance in the association of socioeconomic status with hypertension that could be attributed to variation across countries or regions was approximately 7% for country and 4% for region (Supplemental Table 23).

INTERACTION BETWEEN GDP PER CAPITA AND SOCIOECONOMIC STATUS. In both the Poisson (for relative differences) and linear probability models (for absolute differences), there was a significant interaction with GDP per capita for both the association of educational attainment and household wealth quintile with hypertension. This interaction was especially pronounced for men and in rural areas (Supplemental Figures 17 and 32, Supplemental Tables 24 and 25). Specifically, the lower a country's GDP per capita, the more positive (ie, individuals with more education and household wealth had a higher probability of having hypertension) was the association of education and household wealth quintile with hypertension (**Figure 2**, Supplemental Table 26). This trend was similar irrespective of whether hypertension was defined using the 140/90 mm Hg or the 130/80 mm Hg threshold (Supplemental Figure 33) and regardless of the BP measurement that was used to define hypertension

TABLE 2 Regressions of Hypertension Onto Either Education or Household Wealth Quintile

Education		Household Wealth	
	RR (95% CI)	Quintile	RR (95% CI)
Global			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	1.08 (1.04-1.13)	2	0.98 (0.93-1.02)
Primary school completed	1.11 (1.06-1.16)	3	1.04 (0.99-1.09)
Some high school	1.09 (1.04-1.14)	4	1.06 (1.02-1.11)
High school or above	1.04 (0.99-1.09)	5 (wealthiest)	1.04 (0.98-1.10)
RR for linear trend	1.00 (0.99-1.02)	RR for linear trend	1.01 (1.00-1.02)
Africa			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	1.03 (0.98-1.09)	2	1.00 (0.95-1.06)
Primary school completed	1.00 (0.94-1.06)	3	1.06 (1.00-1.12)
Some high school	1.07 (1.01-1.14)	4	1.16 (1.09-1.23)
High school or above	1.04 (0.97-1.12)	5 (wealthiest)	1.09 (1.02-1.16)
RR for linear trend	1.03 (1.00-1.06)	RR for linear trend	1.04 (1.02-1.05)
Eastern Mediterranean			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	0.99 (0.94-1.04)	2	1.04 (0.98-1.10)
Primary school completed	1.00 (0.94-1.07)	3	1.06 (0.99-1.12)
Some high school	0.91 (0.86-0.97)	4	1.00 (0.94-1.06)
High school or above	0.87 (0.82-0.92)	5 (wealthiest)	1.01 (0.95-1.08)
RR for linear trend	0.93 (0.92-0.95)	RR for linear trend	0.97 (0.96-0.99)
Europe			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	1.04 (0.90-1.20)	2	0.89 (0.72-1.11)
Primary school completed	1.00 (0.87-1.15)	3	0.84 (0.66-1.06)
Some high school	0.99 (0.87-1.14)	4	0.93 (0.79-1.09)
High school or above	0.94 (0.83-1.07)	5 (wealthiest)	0.70 (0.49-1.02)
RR for linear trend	0.90 (0.84-0.97)	RR for linear trend	0.93 (0.87-0.98)
Latin America and the Caribbean			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	1.10 (1.03-1.17)	2	1.03 (0.92-1.14)
Primary school completed	1.12 (1.04-1.21)	3	1.11 (1.00-1.23)
Some high school	1.05 (0.97-1.13)	4	1.06 (0.96-1.18)
High school or above	0.97 (0.90-1.05)	5 (wealthiest)	1.05 (0.95-1.16)
RR for linear trend	0.98 (0.96-0.99)	RR for linear trend	1.02 (0.99-1.04)
South-East Asia			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	1.19 (1.14-1.24)	2	1.05 (1.01-1.09)
Primary school completed	1.18 (1.13-1.24)	3	1.15 (1.11-1.21)
Some high school	1.20 (1.17-1.24)	4	1.27 (1.22-1.33)
High school or above	1.25 (1.20-1.31)	5 (wealthiest)	1.28 (1.22-1.34)
RR for linear trend	1.05 (1.04-1.06)	RR for linear trend	1.07 (1.05-1.08)
Western Pacific			
No formal schooling	1.00 (reference)	1 (poorest)	1.00 (reference)
Some primary school	0.98 (0.88-1.09)	2	0.92 (0.84-1.01)
Primary school completed	1.02 (0.92-1.14)	3	0.99 (0.90-1.09)
Some high school	1.02 (0.91-1.14)	4	0.95 (0.86-1.06)
High school or above	0.93 (0.81-1.05)	5 (wealthiest)	0.98 (0.88-1.09)
RR for linear trend	0.99 (0.96-1.02)	RR for linear trend	1.00 (0.98-1.03)

Standard errors were adjusted for clustering at the primary sampling unit level. Risk ratios (RRs) were obtained from a multivariable regression of hypertension onto either educational attainment or household wealth quintile as a categorical variable, age as a continuous variable, sex as a dichotomous variable, and a binary indicator variable for each country. Linear trends were obtained from a Poisson regression of hypertension onto either educational attainment or household wealth quintile as a continuous variable, age as a continuous variable, and sex as a dichotomous variable, separately for each region.

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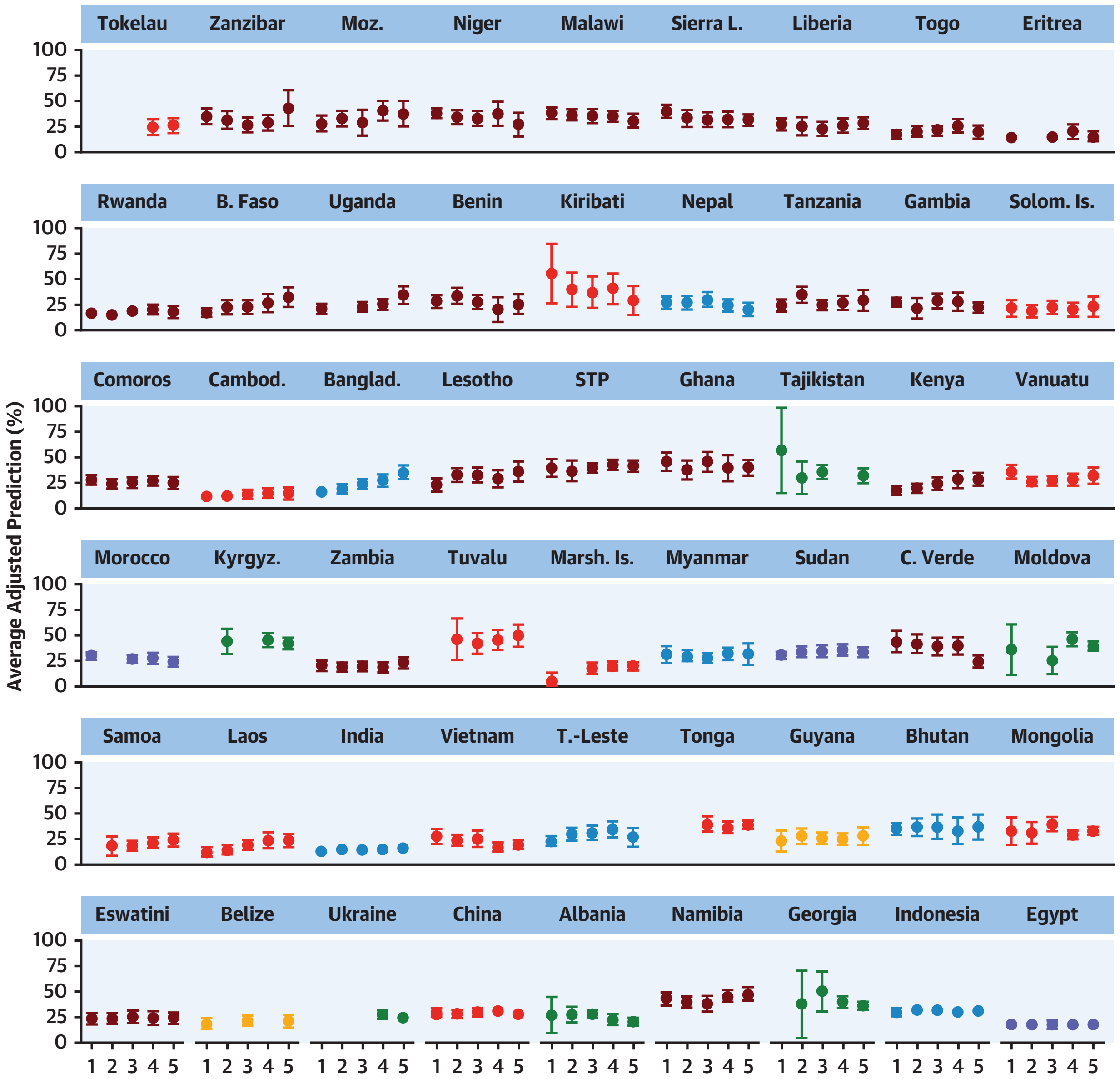
FIGURE 1 Average Adjusted Predictions of Hypertension by Educational Attainment



Average adjusted predictions were obtained from a Poisson regression of hypertension onto educational attainment as a categorical variable, age as a continuous variable, and sex as a dichotomous variable. Countries are ordered by increasing GDP per capita and are color-coded by region. We plotted only those education categories in a country that had >20 observations; Supplemental Table 18 shows all results. **Error bars** depict the 95% CIs. Azerbaij. = Azerbaijan; Banglad. = Bangladesh; B. Faso = Burkina Faso; Cambod. = Cambodia; C. Rica = Costa Rica; C. Verde = Cabo Verde; Kazakh. = Kazakhstan; Kyrgyz. = Kyrgyzstan; Marsh. Is. = Marshall Islands; Moz. = Mozambique; S. Africa = South Africa; Seychell. = Seychelles; Sierra L. = Sierra Leone; S. Lanka = Sri Lanka; Solom. Is. = Solomon Islands; STP = Sao Tome and Principe; SVG = St. Vincent and the Grenadines; T.-Leste = Timor-Leste.

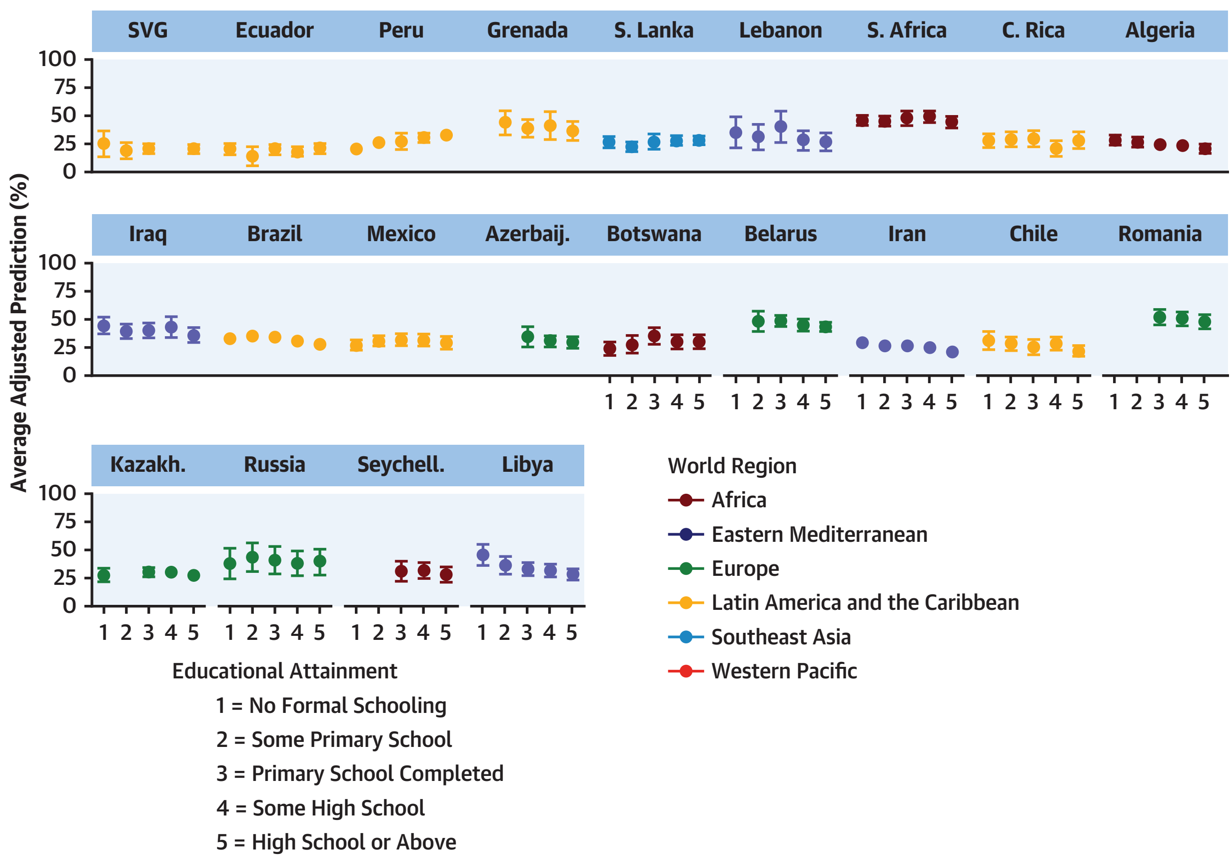
Continued on the next page

(Supplemental Figure 34). In addition, we found similar patterns of the interaction of GDP with the socioeconomic gradient of hypertension for rural and urban populations (Supplemental Figure 17) and after adjusting for BMI (Supplemental Figure 35).

DISCUSSION

This study of cross-sectional, nationally representative, household survey data from 76 countries demonstrates that the view that hypertension mostly

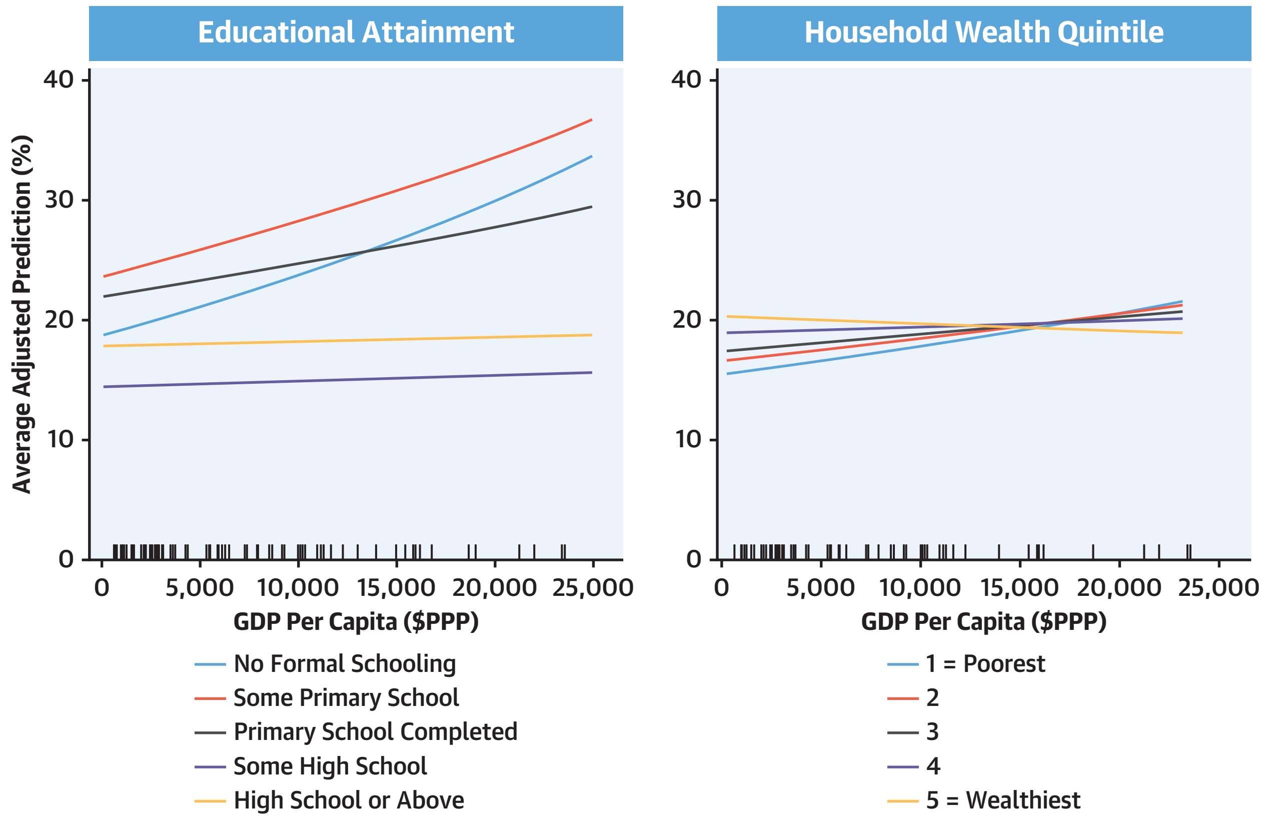
FIGURE 1 Continued



affects the wealthiest and most educated groups in LMICs is largely untenable. We found that the differences in hypertension prevalence between education and household wealth groups were small in most countries. However, these generalizations do not apply to all LMICs that we studied, because there was some important heterogeneity between regions, and LMICs within regions, in the association of socioeconomic status with hypertension. For instance, there was a strong positive association of hypertension with increasing formal education and household wealth in Bangladesh, whereas this was not the case in neighboring India and Nepal.

This study shows that hypertension is common even among the least wealthy and least educated groups in the least economically developed countries. Although previous studies have reported a high prevalence of hypertension in LMICs,[20-23] evidence on the socioeconomic gradients of hypertension within these countries is sparse, as was recently highlighted by The Lancet NCDI Poverty Commission.[24] Our finding may be counterintuitive given that the poorest individuals in LMICs are generally thought to engage in substantial physical activity through manual labor[25] and to not consume excess calories.[26] They also have a relatively low prevalence of overweight and obesity.[27,28] However, some other risk factors for hypertension, such as aging and pollution,[29] tend to affect the entire population, and may thus be responsible for the relatively high hypertension prevalence in these population groups. Policymakers who are concerned with improving health among the most disadvantaged population groups may want to invest in improving hypertension prevention and control among these groups. This appears particularly justified given that we have found in previous research that adults with the least education and household wealth are least likely to reach each step of the hypertension care cascade,[30,31] and that these population groups likely have the least access to high-quality care for cardiovascular disease events.[15,32] However, such health-equity focused investments should ideally be guided by the proportion of the total disease burden among such disadvantaged groups that is caused by hypertension rather than merely hypertension prevalence. In addition, it

FIGURE 2 **Interaction Between GDP per Capita and the Socioeconomic Gradient of Hypertension**



The regression models included age, sex, and either education or household wealth quintile as individual-level predictors; GDP per capita as a country-level predictor; an interaction term between GDP per capita and either education or household wealth quintile; and a random intercept for country. Each **vertical line on the x-axis** represents 1 country. $PPP = constant 2011 purchasing-power-parity-adjusted dollars; GDP = gross domestic product.

is important to highlight that our analysis was constrained to education and household wealth groups, which likely overlooks many other disadvantaged groups in LMICs, such as certain ethnic or religious groups.

Although the strength of this evidence is limited by the cross-sectional design of our analysis, our findings suggest that as GDP per capita increases, socioeconomic gradients of cardiovascular disease and its risk factors tend to reverse—particularly among men—from being positive to less positive, or even to negative. Unlike in a recent analysis by our team for India,[33] this trend was similar regardless of whether education or household wealth quintile was used to measure socioeconomic status. This "reversal hypothesis" has been previously studied using historical data from high-income countries[34,35] and data on obesity from LMICs.[36-41] A large study using Demographic and Health Surveys and World Health Survey data from 103 LMICs concluded that reversals in the socioeconomic gradient of overweight and obesity tended to be driven by increases in overweight and obesity among those with the least household wealth rather than changes in overweight and obesity prevalence among wealthier groups.[27] We observed a similar pattern in our household wealth analysis. Although further evidence from longitudinal studies will be important, our findings suggest the need for policies that aim to reduce a future rise in cardiovascular disease risk factors among poorer segments of the population.

STUDY LIMITATIONS. First, although we used the most recent data available, the associations of household wealth and education with hypertension may have changed in some countries since the year of data collection. However, when we restrict our analysis to surveys that were conducted in 2015 or more recently, the direction and magnitude of these associations remain similar (Supplemental Table 27). Second, the age ranges that were sampled varied substantially across countries. We, thus, restricted the data set to the age group of 25-49 years to compute average adjusted predictions of hypertension by education and household wealth group for each region, because this age group was sampled by all surveys except for Peru. A limitation of this approach is that the association of hypertension with household wealth quintile and education may be different in older age groups. Our analyses presented in the Supplemental Appendix (Supplemental Figures 11, 24, and 25), however, do not suggest that this is the case. Third, not all surveys used the same questionnaire, resulting in differences in how education and household wealth were ascertained. As shown in the Supplemental Appendix, our findings were similar regardless of whether a survey assessed household wealth using dwelling characteristics and household ownership of durable goods or using household income. Nonetheless, the use of questions on household income to assess household wealth is a limitation of this study because households in LMICs often have several sources of income, income may vary substantially between years (eg, for agriculturalists), and home production is common in these settings.[42] Fourth, the included surveys were conducted in different years. The results for a given country should be interpreted as being applicable to the particular survey year, rather than as current. We show the association of socioeconomic status with hypertension for each country ordered by the year of data collection in the Supplemental Appendix (Supplemental Figures 36 and 37). Fifth, although the countries included in this study represent nearly three-quarters (72.5%) of the world's current population living in LMICs,[18] our set of study countries may not be representative for any world region or all LMICs globally. Sixth, the *P* values and CIs should be interpreted in the context of the descriptive purpose of this study rather than as a test of specific hypotheses. Last, the survey from China (CHNS) is not nationally representative for the entire Chinese population.

CONCLUSIONS

Overall, this study shows that hypertension affects countries across regions irrespective of their level of economic development, and affects the full spectrum of socioeconomic groups within countries. Our cross-sectional interaction analyses of GDP per capita with the socioeconomic gradients of hypertension suggest that hypertension may increasingly affect adults in the lowest socioeconomic groups as LMICs develop economically. In combination with the fact that hypertension control rates are low across LMICs and socioeconomic groups,[31] the evidence base on hypertension epidemiology and treatment in LMICs calls for system-wide scale-ups of proven interventions to reduce the prevalence of raised BP.

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PERSPECTIVES

COMPETENCY IN SYSTEMS-BASED PRACTICE: Differences in the prevalence of hypertension between socioeconomic groups in LMICs are relatively small.

TRANSLATIONAL OUTLOOK: Large-scale studies of the disease burden caused by hypertension in LMICs, and how this varies by socioeconomic groups, could better inform health policy in these settings than merely focusing on the prevalence of high BP.

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KEY WORDS education, household wealth, hypertension, low- and middle-income countries, socioeconomic gradient

APPENDIX For an expanded Methods section as well as supplemental figures and tables, please see the online version of this paper.