Diagnostic testing for hypertension, diabetes, and hypercholesterolaemia in low-income and middle-income countries: a cross-sectional study of data for 994 185 individuals from 57 nationally representative surveys

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Summary

Background Testing for the risk factors of cardiovascular disease, which include hypertension, diabetes, and hypercholesterolaemia, is important for timely and effective risk management. Yet few studies have quantified and analysed testing of cardiovascular risk factors in low-income and middle-income countries (LMICs) with respect to sociodemographic inequalities. We aimed to address this knowledge gap.

Methods In this cross-sectional analysis, we pooled individual-level data for non-pregnant adults aged 18 years or older from nationally representative surveys done between Jan 1, 2010, and Dec 31, 2019 in LMICs that included a question about whether respondents had ever had their blood pressure, glucose, or cholesterol measured. We analysed diagnostic testing performance by quantifying the overall proportion of people who had ever been tested for these cardiovascular risk factors and the proportion of individuals who met the diagnostic testing criteria in the WHO package of essential noncommunicable disease interventions for primary care (PEN) guidelines (ie, a BMI >30 kg/m² or a BMI >25 kg/m² among people aged 40 years or older). We disaggregated and compared diagnostic testing performance by sex, wealth quintile, and education using two-sided *t* tests and multivariable logistic regression models.

Findings Our sample included data for 994 185 people from 57 surveys. 19·1% (95% CI 18·5–19·8) of the 943 259 people in the hypertension sample met the WHO PEN criteria for diagnostic testing, of whom 78·6% (77·8–79·2) were tested. 23·8% (23·4–24·3) of the 225 707 people in the diabetes sample met the WHO PEN criteria for diagnostic testing, of whom 44·9% (43·7–46·2) were tested. Finally, 27·4% (26·3–28·6) of the 250 573 people in the hypercholesterolaemia sample met the WHO PEN criteria for diagnostic testing, of whom 39·7% (37·1–2·4) were tested. Women were more likely than men to be tested for hypertension and diabetes, and people in higher wealth quintiles compared with those in the lowest wealth quintile were more likely to be tested for all three risk factors, as were people with at least secondary education compared with those with less than primary education.

Interpretation Our study shows opportunities for health systems in LMICs to improve the targeting of diagnostic testing for cardiovascular risk factors and adherence to diagnostic testing guidelines. Risk-factor-based testing recommendations rather than sociodemographic characteristics should determine which individuals are tested.

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Introduction

For the past three decades, cardiovascular disease has been the most common cause of death in low-income and middle-income countries (LMICs).[1] However, diagnostic testing for risk factors for cardiovascular disease in LMICs has remained low, and 56–69% of adults with one of the three major risk factors for cardiovascular disease—ie, hypertension, diabetes, and hypercholesterolaemia—are undiagnosed.[2–5]

Studies[2–6] in LMICs have assessed the performance of health systems in terms of testing for, diagnosing, treating, and controlling cardiovascular risk factors

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Research in context

Evidence before this study

We searched PubMed with the terms "CVD" OR "cardiovascular disease" AND "screening" AND "low- and middle-income countries" NOT "comment" NOT "case reports" for articles published in any language between Jan 1, 1960, and May 26, 2023. We found systematic reviews of the burden of cardiovascular disease in low-income and middle-income countries (LMICs) and randomised controlled trials of the effectiveness and cost-effectiveness of pilot screening interventions to detect risk factors for cardiovascular disease. We also identified publications by the Global Health and Population Project on Access to Care for Cardiometabolic Diseases, which included continuum of care studies that limit analyses to individuals with a verified diagnosis of hypertension, diabetes, or hypercholesterolaemia. Four studies assessed the diagnostic testing capacity for cardiovascular risk factors of several LMICs. The first used facility-level instead of individual-level data to assess diagnostic capacity for cardiovascular risk factors in ten LMICs. In the second, the diagnostic testing capacity for sociodemographic cardiovascular risk factors was assessed in six LMICs (testing capacity for hypertension, diabetes, and hypercholesterolaemia was not included in the analysis). In the third, a holistic Healthcare Access and Quality Index was generated on the basis of 32 preventable or treatable causes of death (including hypertension and diabetes) for 195 countries. In that study, low prevalence of diagnostic testing would result in a low score on the Index, but so too would other factors, such as poor access to care or low-quality care. In the fourth study, the same modelled data were used as in the third, but the authors examined diagnostic testing and prevalence of hypertension exclusively and disaggregated data by sex only.

Added value of this study

In this study, we provide the largest harmonised, international dataset to date for the diagnostic testing performance of health systems for hypertension, diabetes, and hypercholesterolaemia—major risk factors for cardiovascular disease. Our results show substantial shortcomings in diagnostic testing, as evidenced by the substantial mismatch between people who met WHO's package of essential noncommunicable disease interventions for primary care criteria for testing for cardiovascular risk factors and who were actually tested (with many people meeting the testing criteria not being tested, and conversely many people who did not meet the testing criteria undergoing testing). Testing status was strongly associated with socioeconomic characteristics, with wealthy and educated individuals significantly more likely to be tested than non-wealthy and less educated people.

Implications of all the available evidence

In view of the large and growing burden of cardiovascular disease in LMICs, targeted diagnostic testing efforts for the major risk factors hypertension, diabetes, and hypercholesterolemia, are needed. Health systems in LMICs should redirect cardiovascular risk factor testing to those at highest risk according to guidelines to allow early detection and to prevent exacerbation of disease by enabling timely entry into the care continuum.

among subpopulations with cardiovascular risk factors, but a study of diagnostic testing for these risk factors in the overall populations of LMICs is lacking. In these previous studies, coverage of testing was the largest gap in the care continuum, and this low coverage majorly inhibited the provision of effective, efficient, and timely management of cardiovascular disease. The *Lancet* Commission[7] on diagnostics explicitly identified a lack of diagnostic capacities as the major driver of low testing coverage in LMICs.[8] The UN's Sustainable Development Goals similarly provided an impetus to expand universal health coverage in LMICs and address diagnostics gaps.[9]

Beyond diagnostic testing coverage, analysis of health systems' testing performance should include measures of testing necessity and equity. We define high performance of a health system with regard to diagnostic testing as adherence to the international WHO package of essential noncommunicable disease interventions for primary care (PEN) guidelines, which recommend prioritisation of testing of people at high risk of developing cardiovascular disease.[10] Robust evidence for the performance of health systems in LMICs in terms of testing for hypertension, diabetes, and hypercholesterolaemia and effective and equitable adherence to the WHO PEN guidelines has not previously been published. Furthermore, no previous studies have used individual-level data that link testing data with cardiovascular risk and sociodemographic factors to examine access to testing within health systems in LMICs.

In this study, we analysed diagnostic testing performance for hypertension, diabetes, and hypercholesterolaemia in the health systems of 56 LMICs. We estimated self-reported diagnostic testing and fulfilment of the WHO PEN testing criteria, assessed whether people who met the WHO PEN criteria for testing were actually tested, and analysed how diagnostic testing performance differed by sex, wealth, and education.

Methods

Study design and participants

In this cross-sectional analysis, we used pooled, individual-level data from nationally representative surveys in LMICs. Our methods for identifying and pooling surveys followed the same procedure used in previous studies[2–5,11] and comprised three parts. First, WHO STEPwise approach to surveillance surveys were identified. Second, we searched six survey resources: the

Demographic and Health Surveys, the WHO Study on Global Ageing and Adult Health,[12] the Gateway to Global Aging studies, the Non-Communicable Disease Risk-Factor Collaboration,[13] the Global Health Data Exchange,[14] and the International Diabetes Federation Diabetes Atlas.[15] Finally, we did a systematic Google search in April, 2020. Details of the survey inclusion process and the parameters of our Google search are described in the appendix (pp 2–3).

To be included, surveys had to be nationally representative, provide individual-level data, have been done between Jan 1, 2010, and Dec 31, 2019 in an LMIC (as classified by the World Bank[16] in the survey year), and have contained a question about whether respondents had ever had their blood pressure, glucose, or cholesterol measured. If we were able to access more than one survey for an LMIC, we used the most recent survey.

We included all individuals who were aged 18 years or older, were not pregnant at the time of the survey, had a non-zero survey weight (as determined by the survey team), and had available data for age and BMI. Pregnancy was an exclusion criterion because of the increased probability of undergoing cardiovascular risk factor testing as part of antenatal screening. We created one analysis sample for each risk factor—ie, hypertension, diabetes, and hypercholesterolaemia—because not all surveys included questions about whether respondents had ever had their blood pressure, blood glucose, and cholesterol measured, and the numbers of respondents with missing information for self-reported diagnostic testing status varied (figure 1).

Because our analysis included only previously published data, ethics approval was not required. Each included survey received ethical clearance from the relevant country's ethics review committee before data collection, and all participants consented to the use of their data. The Global Health and Population Project on Access to Care for Cardiometabolic Diseases dataset used in this study was deidentified and therefore deemed Non-Human Subjects Research by the institutional review board of the Harvard T H Chan School of Public Health in 2018 (#IRB16-1915). As such, it was exempted from the need for additional ethics approval.

Outcomes and definitions

We based our analyses on two key outcomes: respondents' diagnostic testing status and fulfilling of the diagnostic testing criteria recommended by the WHO PEN guidelines. For testing status, we constructed three dummy variables for respondents' answers (yes *vs* no) to the question of whether they had had their blood pressure, blood glucose, or cholesterol (ie, fat in the blood) measured by a doctor or health worker. We used the WHO PEN guidelines[10] because they are the international standard for diagnostic testing of non-communicable diseases and to enable cross-country comparisons. More specifically, because there were no global diagnostic testing criteria for all three risk factors and no separate guidelines specifically for hypertension or hypercholesterolaemia, we used the guidelines in the WHO PEN chapter on diabetes[10] as the universal testing benchmark for all three risk factors. The WHO PEN diabetes guidelines recommend testing people who show symptoms of diabetes, who have a BMI greater than 30 kg/m², or who are aged 40 years or older and have a BMI greater than 25 kg/m².[10] However, the included surveys did not collect information on respondents' symptoms (at the time of testing), so we could not consider this criterion in our subsequent analyses. WHO PEN includes guidelines specifically for cardiovascular disease,[10] but we did not use them because the recommendations relied on already knowing individuals' hypertension and diabetes status and did not include guidance about who to test for all three risk factors analysed in this study.

Respondents' sex, height, and weight were recorded by survey administrators. We used height and weight measurements to calculate BMI. We included data for age, education status, and household wealth to study the relationship between these variables and diagnostic testing performance. We grouped education into three categories (less than primary education, at least primary but less than secondary education, and secondary education or more), and used household income or asset ownership data to calculate household wealth quintiles within each country (appendix p 39). Nine surveys did not include data for household assets or income (appendix p 5) and were therefore excluded from the analysis of wealth inequalities in access to diagnostic testing.

Statistical analysis

In each analytic sample, we first assessed the extent to which meeting the diagnostic testing recommendations in the WHO PEN guidelines and testing status overlapped. Second, we ran these analyses disaggregated by sociodemographic characteristics (ie, sex, wealth quintiles, and education status) and tested the significance of the differences between sociodemographic subgroups with a two-tailed, independent, two-sample *t* test for unpaired data with unequal variances. We reported p values after correcting for multiple hypothesis testing according to Benjamini and Hochberg.[17] We additionally calculated 95% CIs for all percentages reported. To corroborate the robustness of the association between sociodemographic characteristics and testing performance, we ran three multivariable logistic regression models, one for each risk factor, among the subsets of people who met the WHO PEN criteria, and reported the findings as odds ratios. Testing status served as the binary outcome variable, and sex, wealth quintile, education, and country dummies comprised the independent variables (appendix p 40). Finally, we disaggregated these analyses by World Bank income group and WHO region (appendix p 41).

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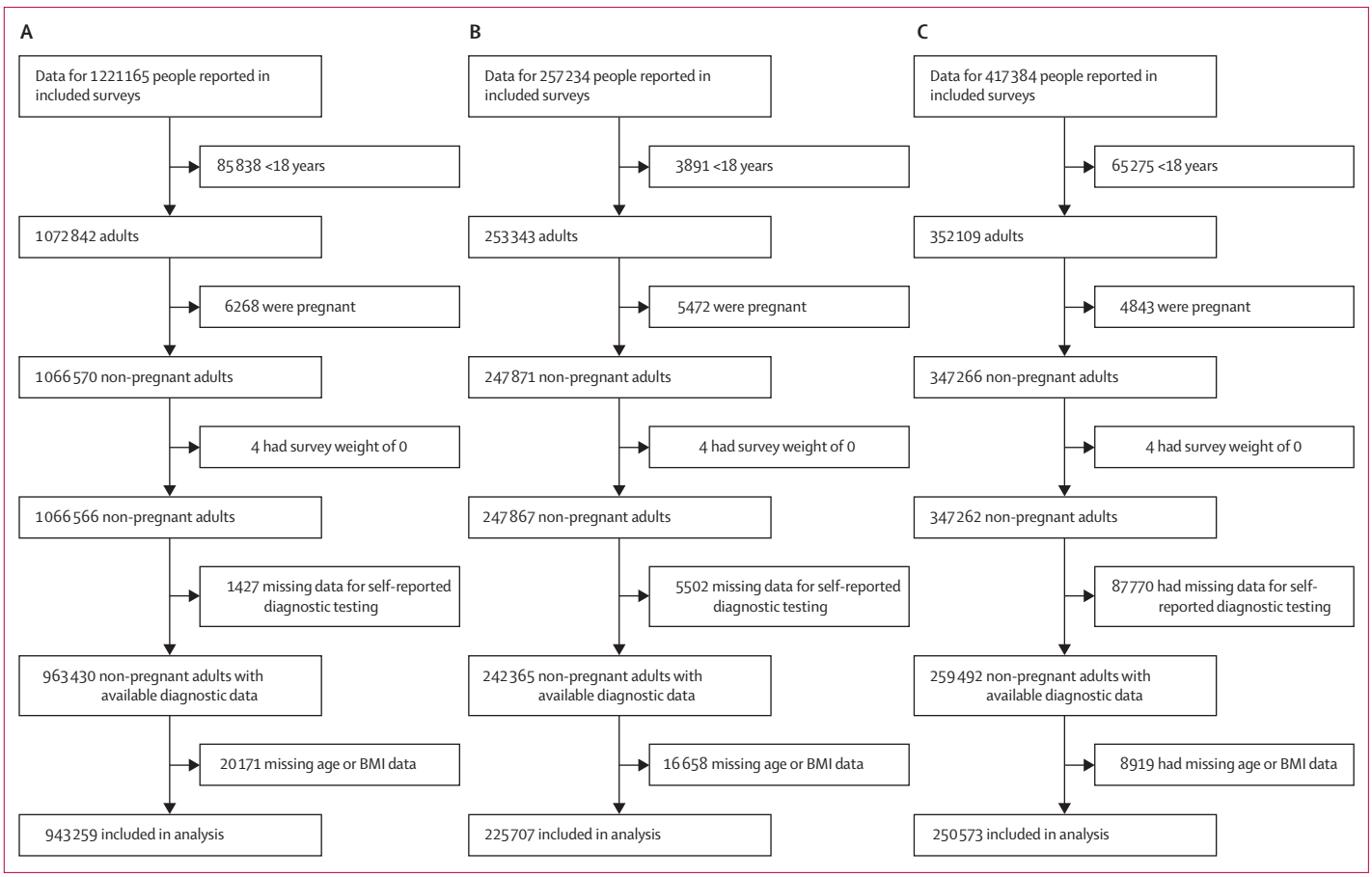

Figure 1: **Selection of hypertension (A), diabetes (B), and hypercholesterolaemia (C) samples**

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For the **Demographic and Health Surveys** see https://dhsprogram.com/

For the **Gateway to Global Aging studies** see https://g2aging.org/

See **Online** for appendix

All analyses were clustered at the primary sampling unit. We adjusted for stratification and applied sampling weights that accounted for unequal probability of selection, non-response, differences between the sample and the target population, missing survey weights, and missingness in covariates. Weights were constructed such that each country's weight corresponded to their 2015 population (appendix p 42).

We did various sensitivity analyses to test the validity of our findings. We re-ran all analyses using equivalent weights whereby survey weights were rescaled such that each country contributed equally to the overall estimates. We also ran the hypertension analyses again but excluded data for India (the most populous contributor in the original analysis) to assess whether these data could skew our results. Finally, we applied three alternative sets of diagnostic testing criteria: the WHO PEN guidelines from the cardiovascular disease chapter[10] for hypercholesterolaemia analyses; the American College of Cardiology and American Heart Association guidelines,[18] which recommend diagnostic testing of all three risk factors for everyone aged 40–75 years (we excluded adults older than 75 years from this sensitivity analysis); and the WHO HEARTS guidelines,[19] which recommend hypertension testing for all adults, for the hypertension analyses. All analyses were done in STATA (version 17.0).

Role of the funding source

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

Results

Our final sample consisted of 57 surveys—49 STEPS surveys and eight non-STEPS surveys—from 56 LMICs (Zanzibar had a survey separate from the rest of Tanzania because it has its own ministry of health and administers its health system largely independently of the rest of Tanzania). Maps of analysis samples (p 4) and survey characteristics by country and individual countries' sampling methods are detailed in the appendix (pp 5–38). Our sample comprised 994185 individuals and was made up of three distinct cardiovascular risk factor samples (figure 1). The hypertension sample included 943259 people in 55 LMICs, the diabetes sample included 225707 people in 53 LMICs, and the hypercholesterolaemia sample included 250573 people in 40 LMICs (table 1). The differences in sample size were due to

	Hypertension (n=943 259)	Diabetes (n=225 707)	Hypercholesterolaemia (n=250 573)
Sex			
Female	729 608 (49·1% [48·7–49·5])	132 743 (51·2% [50·7–51·6])	143 115 (50·7% [50·3–51·1])
Male	213 646 (50·9% [50·5–51·3])	92 960 (48·8% [48·4–49·3])	107 453 (49·3% [48·9–49·7])
Age, years			
Mean	36·1 (12·8)	38·8 (14·1)	40·1 (14·9)
18–39	618 265 (62·8% [62·3–63·3])	106 599 (56·3% [55·7–56·9])	119 710 (52·6% [51·4–53·9])
40–64	305 438 (34·3% 34·0–34·7])	106 871 (39·0% [38·4–39·6])	111 285 (40·8% [39·7–41·8])
≥65	19 556 (2·9% [2·6–3·2])	12 237 (4·7% [4·4–4·9])	19 578 (6·6% [6·0–7·2])
Education			
Less than primary school	242 841 (19·6% [19·2–20·0])	47 353 (19·5% [19·0–20·1])	35 517 (14·4% [13·2–15·6])
Less than secondary school	186 721 (24·7% [24·3–25·1])	74 971 (36·9% [36·1–37·6])	80 354 (35·8% [34·6–47·0])
Secondary completed or higher	510 522 (55·7% [55·1–56·3])	100 314 (43·6% 42·9–44·4])	132 609 (49·9% [48·5–51·3])
Wealth quintile			
1 (poorest)	177 440 (17·9% [17·6–18·2])	36 680 (21·3% [20·6–22·1])	40 813 (18·4% [16·6–20·2])
2	176 015 (18·9% [18·6–19·2])	34 240 (21·3% [20·7–21·9])	42 010 (21·0% [20·0–22·0])
3	176 127 (19·8% [19·5–20·1])	32 955 (19·8% [19·2–20·5])	39 363 (20·1% [19·3–20·9])
4	175 374 (21·1% [20·7–21·4])	30 717 (19·0% [18·3–19·6])	37 328 (20·0% [19·1–20·8])
5 (richest)	174 468 (22·3% [21·8–22·8])	28 790 (18·6% [17·5–19·7])	36 318 (20·6% [19·5–21·7])
BMI, kg/m²			
Mean	23·4 (5·0)	24·1 (5·3)	24·4 (5·1)
<18·5	145 267 (13·5% [13·2–13·8])	17 583 (10·0% [9·6–10·4])	15 081 (8·7% [8·3–9·2])
18·5 to <25	528 744 (56·2% [55·7–56·7])	106 161 (54·6% [54·1–55·1])	110 602 (51·7% [50·7–52·7])
≥25	269 248 (30·3% [29·7–31·0])	101 963 (35·4% [34·9–35·9])	124 890 (39·6% [38·3–40·8])
Cardiovascular risk factor prevalence*			
Hypertension	182 984 (21·6% [21·3–21·9])	69 630 (26·6% [26·0–27·1])	77 402 (28·1% [27·4–28·9])
Diabetes	35 152 (5·3% [5·1–5·5])	14 590 (7·0% [6·7–7·3])	12 289 (7·3% [6·7–8·1])
Hypercholesterolaemia	11 277 (6·6% [6·2–7·1])	11 172 (6·5% [6·2–6·9])	10 263 (7·0% [6·6–7·5])
Testing recommended†	170 810 (19·1% [18·5–19·8])	77 044 (23·8% [23·4–24·3])	93 222 (27·4% [26·3–28·6])
Tested for cardiovascular risk factor	623 594 (63·1% [62·4–63·8])	76 546 (28·6% [28·0–29·2])	96 016 (29·8% [26·9–32·9])

Data are n (% [95% CI]), where n is the number of observations, or mean (SD) for quantitative variables. The number of observations is unweighted, but for calculation of percentages we accounted for sampling design, with survey weights rescaled such that countries' contributions corresponded to their population size. *Defined according to results of the diagnostic testing that took place as part of the surveys. †According to the WHO package of essential noncommunicable disease interventions for primary care guidelines, diagnostic testing was recommended for people with a BMI >30 kg/m² and those older than 40 years with a BMI >25 kg/m².[10]

Table 1: **Sociodemographic characteristics, by cardiovascular risk factor group**

varying availability of self-reported diagnostic testing information (appendix p 5). Women accounted for 49·1% (95% CI 48·7–49·5) of the hypertension sample, 51·2% (50·7–51·6) of the diabetes sample, and 50·7% (50·3–51·1) of the hypercholesterolaemia sample (table 1).

19·1% (95% CI 18·5–19·8) of people in the hypertension sample, 23·8% (23·4–24·3) of people in the diabetes sample, and 27·4% (26·3–28·6) of people in the hypercholesterolaemia sample met the WHO PEN testing criteria (table 1). Self-reported testing was higher for hypertension (63·1% [62·4–63·8]) than for diabetes (28·6% [28·0–29·2]) or hypercholesterolaemia (29·8% [26·9–32·9]; table 1; appendix p 43). Among the 170 810 people in the hypertension sample who met the WHO PEN criteria for testing, 140 951 (78·6% [77·8–79·2]) had undergone diagnostic testing. The corresponding data for the other samples were 41 460 (44·9% [43·7–46·2]) of 77 044 in the diabetes sample and 48 571 (39·7% [37·1–42·4]) of 93 222 in the hypercholesterolaemia sample. Adherence to guidelines—ie, the proportion of the samples for which the fulfilment of testing criteria and testing status coincided (such that those in whom testing was not indicated did not receive a test and those in whom testing was indicated did receive one)—was recorded in 430 757 (49·0% [48·7–49·4]) of 943 259 people in the hypertension sample, 155 037 (72·2% [71·7–72·7]) of 225 707 people in the diabetes sample, and 158 477 (70·6% [69·7–71·4]) of 250 573 people in the hypercholesterolaemia sample. In all three groups, most of the deviations for WHO PEN's testing recommendations were due to people being tested for a risk factor despite there being no indication for such testing (figure 2). Such testing was particularly pronounced in the hypertension group, in which 482 643 (47·5% [95% CI 47·1–47·9]) of 943 259 were tested for hypertension despite not meeting the WHO PEN criteria.

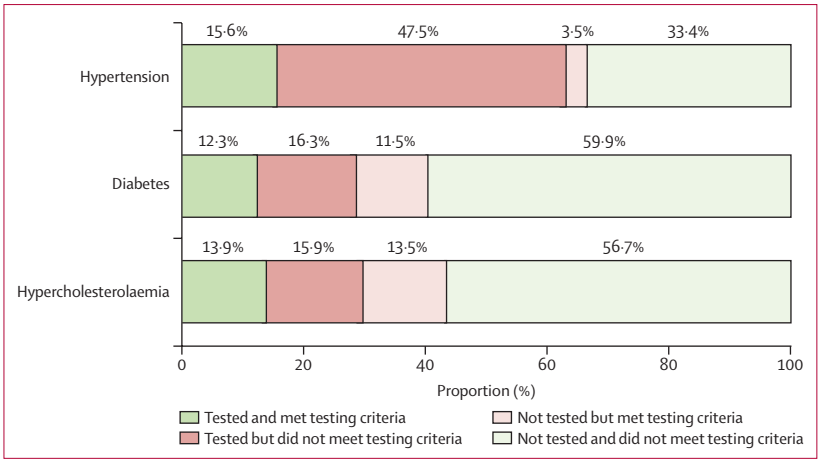

Figure 2: **Adherence to WHO PEN diagnostic testing recommendations, by cardiovascular risk factor**
According to the WHO PEN guidelines, diagnostic testing is recommended for all people with a BMI >30kg/m² and people older than 40 with a BMI >25kg/m².[10] PEN=package of essential noncommunicable disease interventions for primary care.

Diagnostic testing performance varied by individuals' sex, wealth quintile, and education level (figure 3). Women were 5 percentage points more likely than men to meet the WHO PEN criteria (ie, to have a BMI >30 kg/m², or a BMI >25 kg/m² while aged 40 years or older) in the hypertension sample, and approximately 10 percentage points more likely to do so in the diabetes and hypercholesterolaemia samples (appendix p 43). Similarly, women were more likely than men to report having been tested for hypertension (p<0·0001) and diabetes (p<0·0001). Among people who met the WHO PEN criteria, the proportion who were tested was significantly higher among women than men in the hypertension sample (p<0·0001), but did not differ significantly between men and women for diagnostic testing of diabetes or hypercholesterolaemia (appendix p 43). However, adherence to guideline criteria (ie, being tested when testing was indicated, and not being tested when testing was not indicated) was significantly

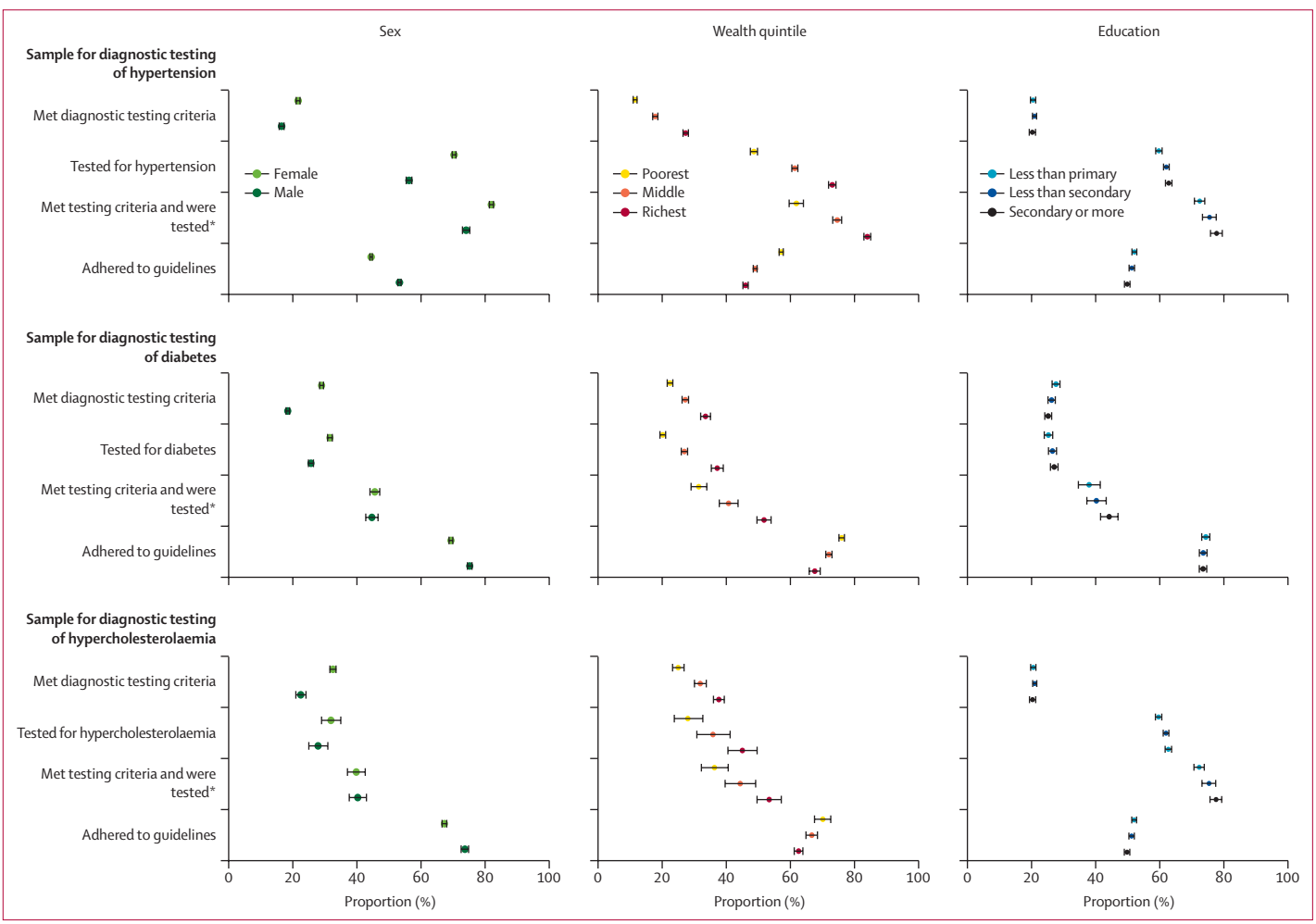

Figure 3: **Diagnostic testing performance by cardiovascular risk factor and sex, wealth, and education categories**
Error bars represent 95% CIs. *The denominator for this proportion is the total number of people who met testing criteria.

higher among men than among women for all three risk factors (figure 3). For hypertension testing, for example, recommendations were adhered to for 113 739 (53·3% [95% CI 52·8–53·8]) of 213 646 men and 317 015 (44·4% [44·1–44·8]) of 729 608 women. This discrepancy was due to a higher proportion of women than men being tested for hypertension despite such testing not being indicated by the WHO PEN criteria (appendix p 45).

Among people who met the WHO PEN criteria, the proportion who had undergone testing was higher among individuals in the wealthiest quintile than those in the other quintiles (figure 3; appendix p 43). Among people meeting the testing criteria for diabetes, 6940 (51·8% [95% CI 49·6–54·0]) of 28 790 individuals in the richest quintile were tested compared with 4850 (31·4% [29·0–33·9]) of 36 680 in the poorest quintile (appendix p 43). Adherence to diagnostic testing criteria was lower in the richest than in the poorest quintiles for all three risk factors (figure 3; appendix p 43). The worse adherence in the richest quintiles was driven by substantial proportions of people being tested for the risk factors despite not meeting the WHO PEN criteria (appendix p 46). Individuals' education level was not strongly associated with their meeting of the WHO PEN criteria or their testing status (figure 3; appendix p 43). Similarly, adherence to guidelines did not seem to differ relative to education for any of the risk factors (appendix pp 43, 47).

Multivariable logistic regressions showed that women were more likely than men to get tested for all three risk factors, as were those with secondary education or more (compared with those with less than primary education) and those in higher wealth quintiles (compared with those in the lowest wealth quintile; table 2). The appendix presents the results disaggregated by World Bank Income Group and WHO World Region (pp 48–52) as well as the results of all sensitivity analyses (pp 53–66), which were largely similar to those of the main analyses.

Discussion

Our study has shown that, in LMICs, diagnostic testing performance for three major CVD risk factors is low, and characterised by large deviations from testing recommendations. We further detected inequalities in access to diagnostic testing by sex and socioeconomic background. Overall, diagnostic testing for hypertension, diabetes, and hypercholesterolaemia—major risk factors for cardiovascular disease—followed socioeconomic gradients in LMICs. Among people who met the criteria in WHO PEN guidelines for diagnostic testing, more educated people and those in higher wealth quintiles were significantly more likely to be tested for all three risk factors. Furthermore, people in higher wealth quintiles were more likely to be tested than those in the lowest wealth quintile even when they did not meet the diagnostic testing criteria, suggesting a suboptimal use of limited diagnostic resources.

On the one hand, a substantial number of individuals who met the WHO PEN criteria were not tested in each sample. On the other hand, we noted diagnostic testing in people who did not meet the WHO PEN criteria—particularly non-indicated testing for hypertension. Comparison of our findings for diagnostic testing coverage with those of previous studies[2–5] suggests that the wider adult population's access to risk factor testing for cardiovascular disease is lower than that of individuals with hypertension, diabetes, or hypercholesterolaemia. This could suggest that countries might be better at targeting diagnostic testing efforts to people at high risk

	Hypertension		Diabetes		Hypercholesterolaemia	
	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Sex						
Male	Ref	..	Ref	..	Ref	..
Female	1·86 (1·74–1·99)	<0·0001	1·21 (1·11–1·33)	<0·0001	1·25 (1·13–1·37)	<0·0001
Wealth quintile						
1 (poorest)	Ref	..	Ref	..	Ref	..
2	1·23 (1·10–1·39)	0·0004	1·12 (0·99–1·26)	0·068	1·11 (0·98–1·27)	0·11
3	1·64 (1·47–1·83)	<0·0001	1·47 (1·27–1·71)	<0·0001	1·64 (1·44–1·87)	<0·0001
4	1·92 (1·71–2·16)	<0·0001	1·66 (1·40–1·97)	<0·0001	2·11 (1·83–2·44)	<0·0001
5 (richest)	2·94 (2·59–3·34)	<0·0001	2·45 (2·13–2·82)	<0·0001	2·87 (2·48–3·33)	<0·0001
Education						
Less than primary	Ref	..	Ref	..	Ref	..
Less than secondary	1·15 (1·04–1·28)	0·0047	1·03 (0·90–1·18)	0·69	0·91 (0·80–1·04)	0·17
Secondary or more	1·39 (1·28–1·52)	<0·0001	1·33 (1·18–1·51)	<0·0001	1·36 (1·20–1·54)	<0·0001

Models included a testing status dummy as the dependent variable and sex, education category, wealth quintile, and country-fixed effects as independent variables. Survey weighting and clustering at the country level were accounted for. PEN=package of essential noncommunicable disease interventions for primary care.

Table 2: **Multivariable logistic regression analysis of associations between diagnostic testing and sociodemographic status among people who met the WHO PEN diagnostic testing criteria**

of cardiovascular disease than our exercise of benchmarking testing performance against WHO PEN recommendations suggested.

Importantly, our study revealed major inequities in risk factor testing by sex, wealth, and education. Although significantly more women than men met the WHO PEN criteria, the proportions of women and men who had been tested (among all people who met the criteria) were equal in the diabetes and hypercholesterolaemia samples. Wealthier individuals were more likely to meet the WHO PEN criteria than those from lower wealth quintiles, and, among those who met the criteria, were more likely to be tested. Significant differences in diagnostic testing performance by educational attainment, however, were detected only via multivariable logistic regression that controlled for sex and wealth, in which individuals with higher educational attainment were more likely to be tested than those with lower educational attainment among people fulfilling diagnostic testing criteria. These differences in diagnostic testing access by sociodemographic characteristics were robust to various sensitivity analyses.

Our study had several limitations. First, we could not assess adherence to the third criterion of the WHO PEN guidelines—testing anyone with symptoms—because our sample did not include data for all possible symptoms at the time of respondents' diagnostic tests. Second, our measure of diagnostic testing (ie, asking respondents if they had previously been tested) did not provide data for why and how often people had been tested. As a result, our weighted means might have been biased—eg, we might have classed respondents who were tested because they had cardiovascular symptoms (despite not meeting the BMI or age criteria) as not meeting the WHO PEN criteria, leading to overestimation of poor adherence. Conversely, although pregnancy at the time of surveying was an exclusion criterion for this study, blood pressure might previously have been measured during pregnancy consultations, which could falsely inflate our estimated share of women fulfilling the WHO PEN criteria and being tested. Accordingly, our chosen measure of at least one previous diagnostic test cannot address the full range of testing rationales or assess testing quality but rather serves as an indicator of individuals having any testing access at all. Third, the WHO PEN diagnostic testing guidelines do not perfectly reflect the risk of developing cardiovascular disease.[20] BMI is an imperfect measure of obesity.[21] Additionally, the guidelines we applied disregard other testing determinants, such as smoking or a history of premature cardiovascular disease, diabetes, or kidney disease in first-degree relatives, all of which are major causes of cardiovascular disease. Fourth, if countries followed national diagnostic testing criteria different from those set out in the international WHO PEN guidelines, our assessments of guideline adherence could have been biased. Fifth, we did not assess access to diagnostic testing by rural versus urban location because many surveys did not record individuals' location category. Sixth, the 56 countries included in this study represent 39·9% of the world population and 47·6% of the population of LMICs, which means that our sample might not be representative of all LMICs. Seventh, even though the mean share of missing outcome data was low, a few countries had substantially higher proportions of individuals without diagnostic testing data (eg, Iraq; appendix p 5), which could have led to selection bias. Eighth, we used self-reported diagnostic testing data, which might be subject to recall or social desirability bias. Ninth, our logistic regression models were based on a timeless outcome variable and time-sensitive predictors, which could have led to people whose age and BMI were close to the guidelines' cutoffs only recently before the survey (rather than at the time of testing) fulfilling the WHO PEN criteria. Finally, we do not claim that the presented associations between sociodemographic characteristics and diagnostic testing performance are causal.

Notwithstanding these limitations, our analysis of testing of cardiovascular risk factors might be the best approximation of diagnostic testing access in LMICs to date. Health policy makers should aim to adhere to diagnostic testing guidelines and mitigate sociodemographic inequalities in testing access and uptake, given that diagnostic testing is the entry point to the care continuum for each of the presented risk factors and has major implications for downstream control of cardiovascular disease.[2–6]

Contributors

SO, IvP, RA, JM-G, and SV conceived the study. M-EM, MT, DF, JD, PG, TB, RA, JM-G, and SV led the data curation, with input from KA, KKA, SB, BB, PB, LCCB, DCM, AD, FF, GG, AG, MG, DG, CH, DH, NH, JAJ, KBK, NL, JM, MM, SSM, OM, KJM, BN, SQ-C, NR, AMS, LS, LT and RW-M. SO led the formal analysis, with substantial contributions from IvP, RA, JM-G, and SV. SO and IvP wrote the first draft of the Article, with substantial contributions from RA, JM-G, and SV. All authors had full access to the data, which were verified by SO, IvP, RA, JM-G, and SV. All authors provided input on several versions of the Article, read and approved the final version, and had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Deidentified participant-level data used in this study can be obtained via the Data Resource Profile.[11]

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