Published in final edited form as:

Lancet Diabetes Endocrinol. 2017 March ; 5(3): 196–213. doi:10.1016/S2213-8587(17)30015-3.

Laboratory-based and office-based risk scores and charts to predict 10-year risk of cardiovascular disease in 182 countries: a pooled analysis of prospective cohorts and health surveys

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See **Online** for appendix

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Contributors

PU, YL, and KH analysed cohort and survey data and prepared results. PU, MW, ME, and GD wrote the manuscript with input from all coauthors. MW, ME, and GD conceived the study, with input from JAS. RA-W, CAA-S, AA, FA, JB, RC, MDC, LE, FF, TSF, NI, DK, Y-HK, VL, LL-M, DJM, PM, KPM, GM, KO, SO, FR-A, RR-M, GV, RW, JES, GAS, JST, and BZ collected and managed risk factor, survey, or external cohort data. GD and ME oversaw the research. GD is the study guarantor.

Declaration of interests

All other authors declare no competing interests.

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Summary

Background—Worldwide implementation of risk-based cardiovascular disease (CVD) prevention requires risk prediction tools that are contemporarily recalibrated for the target country and can be used where laboratory measurements are unavailable. We present two cardiovascular risk scores, with and without laboratory-based measurements, and the corresponding risk charts for 182 countries to predict 10-year risk of fatal and non-fatal CVD in adults aged 40–74 years.

Methods—Based on our previous laboratory-based prediction model (Globorisk), we used data from eight prospective studies to estimate coefficients of the risk equations using proportional hazard regressions. The laboratory-based risk score included age, sex, smoking, blood pressure, diabetes, and total cholesterol; in the non-laboratory (office-based) risk score, we replaced diabetes and total cholesterol with BMI. We recalibrated risk scores for each sex and age group in each country using country-specific mean risk factor levels and CVD rates. We used recalibrated risk scores and data from national surveys (using data from adults aged 40–64 years) to estimate the proportion of the population at different levels of CVD risk for ten countries from different world regions as examples of the information the risk scores provide; we applied a risk threshold for high risk of at least 10% for high-income countries (HICs) and at least 20% for low-income

and middle-income countries (LMICs) on the basis of national and international guidelines for CVD prevention. We estimated the proportion of men and women who were similarly categorised as high risk or low risk by the two risk scores.

Findings—Predicted risks for the same risk factor profile were generally lower in HICs than in LMICs, with the highest risks in countries in central and southeast Asia and eastern Europe, including China and Russia. In HICs, the proportion of people aged 40–64 years at high risk of CVD ranged from 1% for South Korean women to 42% for Czech men (using a 10% risk threshold), and in low-income countries ranged from 2% in Uganda (men and women) to 13% in Iranian men (using a 20% risk threshold). More than 80% of adults were similarly classified as low or high risk by the laboratory-based and office-based risk scores. However, the office-based model substantially underestimated the risk among patients with diabetes.

Interpretation—Our risk charts provide risk assessment tools that are recalibrated for each country and make the estimation of CVD risk possible without using laboratory-based measurements.

Introduction

Cardiovascular diseases (CVDs) are the leading cause of death and disability worldwide, and over three-quarters of CVD deaths occur in low-income and middle-income countries (LMICs).¹ An effective strategy for CVD prevention is to provide lifestyle counselling to people at high risk of an event, with or without prescription of medications to lower blood pressure and serum cholesterol. As part of the global response to non-communicable diseases (NCDs), countries have agreed to a 50% target for coverage of counselling and treatment for people who are at high risk of CVDs, including ischaemic heart disease (IHD) and stroke.^{1,2}

The risk-based approach to CVD prevention requires identification of high-risk people (eg, those with 30% risk of having a cardiovascular event in 10 years),^{2,3} which is done with risk prediction equations, often presented as risk charts. A risk prediction equation estimates a person's risk of CVD during a specific time period using measures of their CVD risk factors and a set of weights, usually log hazard ratios, that quantify the proportional effect of each risk factor on CVD risk. Risk equations developed in one population cannot be applied to other populations, or even used in the same population years after they were developed, because mean CVD risk and CVD risk factor levels vary across populations and over time.^{4,5} This challenge can be dealt with by recalibrating the risk prediction equation; that is, resetting the mean risk factor levels and disease risk to current levels for the target population.^{6–8} However, such recalibration is rarely done because most countries do not have the information needed, and current risk equations are difficult to recalibrate.⁹ A previous set of risk charts published by WHO only provided predicted CVD risk for regions and not individual countries.³ The absence of reliable contemporary risk charts for all countries presents a major obstacle for worldwide implementation of risk-based prevention. A second obstacle is that most risk prediction equations require measurements of blood glucose and lipids, which makes implementation of risk assessment too costly or impractical in resource-poor settings.

We previously presented a novel approach for risk prediction in global populations (Globorisk)⁹ and applied the methods to predict 10-year risk of fatal CVD in 11 countries. Here, we used the same methods to estimate the 10-year risk of fatal and non-fatal CVD and to recalibrate the models using updated data for 182 countries. We also generated corresponding risk charts using an alternative model that relies only on risk factors that do not require blood tests. We then assessed a two-stage strategy using a combination of the two risk scores to identify high-risk individuals and limit the number of patients who need laboratory tests.

Methods

Statistical analysis and coefficients of risk prediction equations

As described in detail elsewhere,⁹ we generated a laboratory-based risk prediction equation using data from eight cohort studies in the USA and a Cox proportional hazards model stratified by sex and cohort that used age as the timescale.¹⁰ Risk factors used in the laboratory-based mode included smoking, blood pressure, diabetes, and total cholesterol. We allowed the coefficients of risk factors to vary with age because CVD hazard ratios often decrease by age.¹¹ We also included interaction terms between sex and diabetes and sex and smoking, because diabetes and smoking are stronger predictors of CVD in women than in men.^{12,13} Fatal and non-fatal CVD comprised deaths from IHD, sudden cardiac death or stroke (International Classification of Diseases [ICD] 10 codes I20–I25 and I60–I69) and nonfatal myocardial infarction (ICD-10 codes I21–I22) and stroke (ICD-10 codes I60–I69).

We then modified this model to generate an office-based model, in which we replaced total cholesterol and diabetes with BMI because there is a strong association between BMI and both diabetes and cholesterol because of the direct effect of excess weight on these physiological traits.¹⁴ Additionally, common factors such as poor diet and physical inactivity contribute to increased bodyweight, blood glucose, and serum cholesterol. As supported by previous research,¹⁵ an interaction term between sex and BMI did not improve risk prediction, and was therefore not included.

We did an internal validation of the models by assessing the ability of the risk score to assign a higher risk to individuals with a shorter time to event (discrimination) using Harrell's C statistics and by comparing the predicted and observed 10-year risk by deciles of risk (calibration; appendix pp 2, 3). We compared the proportion of participants who went on to develop CVD during follow-up who were categorised as high risk by the two risk scores (sensitivity), as well as the proportion of participants who were free of CVD at the end of follow-up who were categorised as low risk (specificity) using 10%, 20%, and 30% 10-year CVD risk as thresholds for high risk versus low risk. Finally, we did an external validation of the model in three cohorts that had not been used to estimate the risk prediction equation (Tehran Lipid and Glucose Study, Scottish Heart Health Extended Cohort, and The Australian Diabetes, Obesity and Lifestyle Study; appendix p 7).

Recalibration of the risk scores

The recalibration procedure is described in detail elsewhere.⁹ Briefly, we replaced mean risk factor levels and CVD event rates in each 5-year age group and by sex with the best current estimates of these quantities for the target country. Age-specific and sex-specific estimates of mean risk factor levels were taken from global analyses of health examination surveys.^{16–20} We estimated fatal and non-fatal IHD and stroke rates for each country and age and sex group by dividing the WHO IHD and stroke death rates²¹ by the case fatality rates.

To obtain case fatality estimates, we first considered that case fatality varies by region and is higher in LMICs than high-income countries (HICs).^{22,23} We thus used previously published estimates of 28-day case fatality rates by region for IHD²² and by country income level for stroke,²³ and converted these to 1-year case fatality rates using methods explained in the appendix (appendix pp 3–6, 8). Case fatality also increases with age. To convert the all-age case fatality rates to age-specific rates, we used the age pattern of 1-year case fatality rates reported in nationwide Swedish registries (appendix pp 3–6, 13, 14).

The total (fatal and non-fatal) CVD rate in each age and sex country group was calculated as:

$$\text{CVD} = \text{fatal IHD} + \text{fatal stroke} + [1 - (1 - \text{non-fatal IHD}) \times (1 - \text{non-fatal stroke})]$$

This formula allows for the potential overlap between non-fatal IHD and stroke (eg, a stroke event in the same person after a non-fatal IHD), which tends to happen in people in whom IHD and stroke rates are higher (eg, elderly people), therefore reducing potential bias when simply adding non-fatal IHD and stroke rates. In the eight US cohorts, we estimated that simply adding non-fatal IHD and stroke rates would overestimate the observed CVD rates by three to 31 per 1000 person-years, whereas the aforementioned method reduces the bias by up to 63%. Once fatal and non-fatal CVD rates were estimated, they were projected for 9 years (ie, 2016–24) using trends from 2000–15 and a log-linear model.

We used the recalibrated risk scores to generate risk charts for 182 of the 193 WHO member states for which we had data on CVD death. In the main paper, we present risk charts for the most populous countries in each region as examples. We limited prediction to those aged 40–74 years because this range is commonly used for assessment of primary prevention of CVD, and CVD death rates in those aged 85 years and older are less reliable.

Application in national surveys

We used the recalibrated laboratory-based risk equation and individual-level data from nationally representative surveys to estimate the proportion of the population at different levels of CVD risk in ten countries with recent (2007 or later) surveys (appendix p 9). Since surveys in Cambodia, Czech Republic, Iran, and Uganda only included people aged 40–64 years, we used this age range to compare the proportion of individuals who are at high risk across the ten countries. For each country, we compared the mean 10-year risk of fatal CVD from the previously published Globorisk model,⁹ with the 10-year risk of fatal and non-fatal CVD predicted by the updated laboratory-based and office-based risk scores. We also used

scatter plots to compare predicted risks for each individual and estimated the proportion of men and women who were categorised as low risk or high risk by the two risk scores. We considered three different thresholds to define high risk: 10% for HICs, 20% in LMICs on the basis of recent guidelines,^{3,24–26} and 30% in LMICs as the threshold used in the global NCD target.²

We also assessed a two-stage strategy that could be used to identify high-risk individuals in resource-poor settings. In this strategy, patients would be first assessed using the office-based risk score and those with a predicted risk that was just below the threshold for high risk (ie, potential false negatives) would be referred for further laboratory testing. We then estimated the proportion of patients at high risk who were identified by the office-based risk score and established the range of office-based risk levels at which further laboratory tests would be needed to identify 95% of those at high laboratory-based risk.

Analyses were done with Stata 12.0. The study protocol was approved by the institutional review board at the Harvard T.H. Chan School of Public Health (Boston, MA, USA).

Role of the funding source

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

Results

We included 50 129 participants from eight cohorts in the estimation of the proportional hazards models; characteristics of the population were reported previously.⁹ Table 1 shows the coefficients for the risk scores. Both risk scores performed well in internal and external validation (appendix p 11). In the internal validation, the C statistic was 0·71 (95% CI 0·70–0·72) for the laboratory-based model and 0·69 (0·68–0·70) for the office-based model. In the external validation, the C statistic ranged from 0·73 to 0·78 for the laboratory-based model and from 0·70 to 0·77 for the office-based model (appendix p 12). Both models predicted risks that were close to those observed in internal and external validation (appendix pp 11, 12).

The mean 10-year risk of fatal and non-fatal CVD was similar between the two risk scores and was higher than the risk of fatal CVD (table 2). In the pooled eight US cohorts and using 10% as the risk threshold, the laboratory-based risk score categorised 1956 (65·1% [95% CI 64·2–65·9]) and the office-based risk score categorised 1881 (62·6% [61·7–63·5]) of the 3005 participants who later had a CVD event as high risk (appendix p 10).

At any age and risk factor level, the 10-year risk of CVD varied substantially across countries for both models. Overall, predicted risks in the country risk charts were lower in HICs than in LMICs, with the highest risks estimated for the same risk profile in southeast and central Asia and eastern Europe (appendix pp 23–388). Figure 1 shows risk charts based on the laboratory-based model for ten highly populous countries. The predicted 10-year CVD risk for a non-smoking 65-year-old man with diabetes, a systolic blood pressure of 160

mm Hg, and a total cholesterol of 6 mmol/L spanned from 21% in Japan and the USA to 53% in China, and the predicted risks for the same profile for a smoker ranged from 26% in Japan to 62% in China (figure 1). The complete set of risk charts is presented in the appendix (pp 23–388) and a risk calculator is available from Globorisk.

Distribution of 10-year risk of CVD using the laboratory-based model varied substantially across countries (figure 2). The share of the population with an at least 10% CVD risk in the four HICs ranged from 7% for men and 1% for women in South Korea to 42% for men and 15% for women in the Czech Republic. In the four middle-income countries, the percentage of population with at least 20% CVD risk ranged from 3% for men and 2% for women in Jamaica to 13% for men and 11% for women in Iran. In the two low-income countries, the percentage of people who had at least 20% risk was less than 2% in Uganda and 9% in Cambodia in both men and women.

When using a 10% risk threshold for high risk in HICs, the two risk scores assigned the same risk status to 85–93% of men and 89–95% of women in each country (figure 3). The corresponding percentages using a 20% threshold for middle-income countries were 90–96% in men and 89–95% in women; and for low-income countries they were 94–95% to 99% for both men and women (figure 3; appendix pp 389–95). The largest differences between the risks estimated using the two models occurred among people with diabetes, in whom the office-based model underestimated risk by 23–75% at various ages across the ten countries (figure 4, appendix pp 389–95). Accordingly, the proportion of the population correctly categorised as low risk or high risk using the office-based model was lower in countries with a high diabetes prevalence (eg, Mexico and Iran; figure 3).

Figure 5 shows the potential of a two-stage strategy to identify individuals with high CVD risk in ten countries. In the four HICs shown, the percentage of individuals at high risk (≥ 10% laboratory-based CVD risk) who were identified correctly by the office-based risk score (ie, sensitivity) was 66–82% among men and 36–71% among women (figure 5). In these countries, between 14% and 61% of the population who had a borderline risk would need further laboratory tests to identify 95% of those at high risk. In LMICs, the proportion of high-risk (≥ 20% laboratory-based CVD risk) individuals who were identified correctly by the office-based risk score varied from 33% to 83%, and the percentage of the population that would need laboratory tests to correctly identify 95% of those at high risk ranged from 11% to 50%.

Discussion

We developed CVD risk charts to predict fatal and non-fatal CVD, with and without laboratory-based measurements, for 182 countries. These risk charts will facilitate worldwide implementation of risk-based prevention by providing health-care professionals with risk assessment tools that are recalibrated for each country and can be used in settings without access to laboratory-based measurements. The predicted risk for the same risk factor profile tended to be lower in HICs than in LMICs, a pattern that was also reported in the Prospective Urban and Rural Epidemiological study.²⁷ When risk scores were applied to

data from national health surveys, prevalence of high CVD risk varied substantially by country and sex and was generally lower in HICs than in LMICs.

Our risk scores and risk charts will be particularly useful in LMICs because most of these countries do not have locally developed risk scores. Additionally, the office-based risk score allows for risk prediction in environments where there is little or no access to a laboratory, such as during home care visits. Similar to findings from previous research,²⁸ more than 80% of adults were similarly classified as low risk or high risk by laboratory-based and office-based risk scores. However, we noted that the office-based risk score substantially underestimated the risk among people with diabetes.

In several LMICs (eg, Uganda, China, and Jamaica), a two-stage strategy using the 20% risk threshold for high risk seemed efficient because a relatively small proportion (11–30%) of individuals with borderline office-based risk would need further laboratory tests to detect 95% of high-risk individuals. By contrast, about half of women in Cambodia and men in Mexico would need further laboratory tests. Further development of office-based risk scoring strategies should use country-specific risk thresholds and balance the benefits of reducing costs with the possibility of missing truly high-risk individuals. Where a difference was noted between the laboratory-based and office-based scores, it was mostly among patients with diabetes, highlighting the importance of including a diagnosis of diabetes in the risk score if laboratory measurements are available. Also, inclusion of diabetes in the laboratory-based risk score would further motivate screening for diabetes, which remains largely undiagnosed in LMICs.²⁹ Therefore, integrating diabetes diagnosis into CVD risk stratification programmes will improve early detection and management of diabetes and risk-based CVD prevention.

Most existing risk scores have been developed for specific populations.^{30,31} WHO developed regional risk charts in 2007,³ but individual coefficients of the risk score were not derived from the same regression model or even from a consistent set of epidemiological studies. Moreover, risk charts were only presented for regions and not for individual countries, although CVD risk differs between countries in the same region.²¹ The only other country-specific risk score, the Systematic Coronary Risk Evaluation (SCORE), provides risk charts for European countries.³² However, the charts only predict risk of fatal CVD, which disfavors younger individuals who have a proportionally higher risk of non-fatal CVD. Moreover, SCORE risk charts do not include diabetes, which is an important predictor of CVD.

In addition to providing a unified risk score and risk charts that can be used for all countries, our risk charts can be easily updated as new national data on mean risk factor levels and CVD rates become available. Our risk scores also include interactions between age and risk factors. The age interactions improve risk prediction, and, because the interactions are negative, they help to highlight the need for intervention in younger individuals with increased risk factor levels whose lifetime risk of CVD is high.³³ In fact, as evident in the risk charts, the predicted risk for individuals with high levels of several risk factors does not increase substantially with age. Other strengths of the study are the use of high-quality prospective cohorts to estimate risk score coefficients, and application of the risk score to

individual-level, national data from countries in different world regions to estimate prevalence of high CVD risk. The use of national in-country data is distinct from the summary statistics used in the 2007 WHO report,³ which do not take into account associations between different CVD risk factors in each country.

Our study has some limitations. First, because national CVD incidence data are not available for most countries, we estimated fatal and non-fatal CVD rates using national IHD and stroke death rates from WHO,²¹ and estimates of case fatality rates by age, sex, and region.^{22,23} Our estimated CVD rates were close to those reported in nationwide studies and health registries in several HICs. However, this estimation had a few limitations: (1) WHO death rates in countries with incomplete vital registration are estimated using partial information and demographic and epidemiological methods;³⁴ (2) we used the age pattern of case fatality from Sweden, where high-quality data were available from more than 1 million events in registries, because age-specific case fatality rates were not available from other countries; and (3) the CVD rates that we used for recalibration overestimated the true rates because we ignored the positive association between non-fatal IHD and stroke events because of their shared risk factors. Empirical data to quantify this association for all countries are not available. The scarcity of data on CVD rates underscores the need for monitoring. Second, although the coefficients of the risk scores were derived from eight high-quality cohorts of diverse ethnic origins, all cohorts were from the USA and Puerto Rico. Evidence from cohort pooling shows that the proportional effects of risk factors are similar in so-called western (North America, western Europe, Australia, and New Zealand) and Asian populations, and over time in the same populations.^{11,35} Future research should include pooling studies across different regions. Third, in our application of the risk score in country surveys, we did not account for patients with a previous CVD event who are at high risk of a future event and should receive treatment. Fourth, we used 10%, 20%, and 30% as thresholds to define high risk on the basis of national and international guidelines for CVD prevention.^{3,24–26} However, the threshold above which a patient is judged to be high risk and thus eligible for counselling and treatment depends on the priorities set for disease control in each country. The threshold also changes the sensitivity and specificity of the risk score, which also vary across countries. Finally, we presented 10-year CVD risk because this is the most commonly used timeframe in risk scores and risk charts. However, 10-year risks underestimate lifetime risk and might therefore lead to under-treatment, especially in younger individuals.

Risk-based prevention of CVD is a major strategy proposed by national and international guidelines.^{3,24,25} The risk charts presented here can be used to predict 10-year risk of fatal and non-fatal CVD in 182 countries worldwide, removing a major obstacle in applying risk-based prevention strategies both for individuals and populations. Further research is needed to identify the most cost-effective interventions for high-risk individuals. Trials are ongoing to establish whether the efficacy of multidrug treatment and lifestyle advice in LMICs is similar to those in high-income countries. Research is also ongoing into whether non-physician clinicians, aided by new information technologies such as risk charts, can successfully identify and manage high-risk individuals, especially if regular contact leads to better adherence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors alone are responsible for the views expressed in this Article and they do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated. PU was partly funded by the US National Institutes of Health (NIH; NIDDK: 1R01-DK090435), The Swedish Society of Medicine, and Gålöstiftelsen. Data from prospective cohorts were obtained from the National Heart, Lung, and Blood Institute (NHLBI) Biologic Specimen and Data Repository Information Coordinating Center. This study does not necessarily reflect the opinions or views of the cohorts used in the analysis, or the NHLBI. This research also uses data from the China Health and Nutrition Survey (CHNS). We thank the National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention, Carolina Population Center (5 R24 HD050924), the University of North Carolina at Chapel Hill, the NIH (R01-HD30880, DK056350, R24 HD050924, and R01-HD38700), and the Fogarty International Center of the NIH for financial support for the CHNS data collection and analysis files from 1989 to 2011. We thank the China-Japan Friendship Hospital, Ministry of Health of China for support for CHNS 2009. Access to individual records of the National Health and Nutrition Survey was obtained under the Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (grant number: 24590785).

MW has received fees from Amgen for being a research project consultant.

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Research in context

Evidence before this study

We searched PubMed (last search done Oct 1, 2016) for articles related to cardiovascular disease (CVD) risk prediction in global populations using the following key terms: “cardiovascular disease”, “risk prediction”, “risk score”, “risk equation”, “developing countries”, “low-income and middle-income countries”, and “global”. No language restrictions were set. We reviewed the 209 articles retrieved from this search to find those that included risk prediction equations that could be applied to more than one country. Only three risk prediction equations qualified for our review and each had major limitations. WHO presented regional risk charts in 2007; however, the individual coefficients of the risk score were not derived from the same regression model or even from the same set of epidemiological studies, and cardiovascular risk patterns might differ between countries in the same subregion. The Systematic Coronary Risk Evaluation (SCORE) provided separate risk charts for European countries, but the risk charts only predicted risk of fatal CVD and did not include diabetes, which is an important predictor of CVD. Finally, the INTERHEART Modifiable Risk score was developed from a multi-country case-control study, unlike other models that are based on prospective cohorts, and did not include stroke as an outcome.

Added value of this study

We provided risk scores, with and without laboratory-based measurements, for prediction of 10-year risk of fatal and non-fatal CVD and recalibrated the risk scores to produce risk charts for 182 countries. The two risk scores are designed in a way that allows and necessitates updating as new data on mean risk factor levels and CVD rates become available.

Implications of all the available evidence

Our risk charts facilitate worldwide implementation of risk-based prevention by providing health-care professionals with risk assessment tools that are recalibrated for each country and can be used in settings without access to laboratory-based measurements.

Figure 1. Laboratory-based country risk charts for 10-year risk of fatal and non-fatal cardiovascular disease for ten highly populous countries

To establish a person's risk, identify the column that represents the person's sex, smoking, and diabetes status. Then identify the closest cell that represents the person's age, total cholesterol, and systolic blood pressure.

Figure 2. Distributions of 10-year risk of fatal and non-fatal cardiovascular disease by country and sex in people aged 40–64 years using the laboratory-based model
 Countries are ranked by mean risk in the population for each sex. HIC=high-income country. LIC=low-income country. MIC=middle-income country.

		High risk defined as $\geq 10\%$				High risk defined as $\geq 20\%$				High risk defined as $\geq 30\%$			
Office-based risk score		Low risk		High risk		Low risk		High risk		Low risk		High risk	
Laboratory-based risk score		Low risk	High risk	Low risk	High risk	Low risk	High risk	Low risk	High risk	Low risk	High risk	Low risk	High risk
Uganda (LIC)	Men	82.8	2.4	5.4	9.4	98.3	0.7	0.6	0.4	99.6	0.1	0.3	0.0
	Women	85.7	1.0	5.4	7.8	97.6	0.7	0.3	1.4	98.9	0.0	0.7	0.4
Cambodia (LIC)	Men	48.4	4.3	5.5	41.8	87.8	2.5	2.8	6.8	96.0	1.2	1.1	1.7
	Women	63.0	4.4	5.2	27.4	88.4	3.6	2.1	5.8	95.4	2.5	0.6	1.4
China (MIC)	Men	50.6	5.8	2.3	41.3	75.2	3.8	2.2	18.7	88.2	3.0	1.5	7.3
	Women	57.9	4.8	3.6	33.8	78.7	4.7	2.6	14.0	89.1	4.4	1.7	4.8
Spain (HIC)	Men	71.6	6.7	4.4	17.3	96.3	1.9	0.6	1.3	99.5	0.4	0.0	0.1
	Women	88.7	3.3	2.3	5.7	98.1	1.3	0.2	0.4	99.7	0.3	0.0	0.0
South Korea (HIC)	Men	83.1	5.0	2.0	9.9	98.3	1.2	0.1	0.4	99.7	0.3	0.0	0.0
	Women	89.4	2.4	2.4	5.8	97.7	1.7	0.2	0.4	99.4	0.5	0.1	0.0
Czech Republic (HIC)	Men	52.2	7.5	6.1	34.3	88.6	5.8	1.6	4.1	96.9	2.4	0.4	0.2
	Women	82.2	6.4	2.9	8.6	96.5	2.2	0.4	0.9	99.0	0.8	0.0	0.2
USA (HIC)	Men	65.6	8.8	5.8	19.8	95.3	2.6	0.0	2.1	98.2	1.2	0.1	0.6
	Women	83.6	8.5	3.1	4.9	97.5	1.6	0.8	0.1	99.6	0.4	0.0	0.0
Mexico (MIC)	Men	65.6	8.9	5.4	20.0	91.3	3.9	1.2	3.7	97.6	1.6	0.3	0.4
	Women	75.3	6.3	5.3	13.2	92.0	4.2	1.1	2.8	96.7	2.4	0.0	0.9
Iran (MIC)	Men	44.2	6.0	11.5	38.3	83.5	5.7	3.9	6.9	96.1	2.1	0.7	1.0
	Women	59.9	7.2	10.3	22.6	85.5	7.3	3.6	3.6	94.8	3.7	0.7	0.7
Jamaica (MIC)	Men	66.1	4.3	3.5	26.1	90.7	2.9	1.2	5.2	97.6	1.0	0.3	1.1
	Women	74.3	6.1	4.1	15.5	90.7	4.7	2.4	2.2	97.5	1.5	0.1	0.9

Proportion of population correctly categorised by office-based risk score

$\geq 95\%$
 ≥ 90 to $<95\%$
 ≥ 85 to $<90\%$
 ≥ 80 to $<85\%$

Figure 3. Percentage of the population in national health surveys categorised as high or low risk by the office-based and laboratory-based risk scores at three different threshold levels used to define high risk

Countries are ordered by increasing diabetes prevalence. The surveys for Cambodia, Czech Republic, Iran, and Uganda include people aged 40–64 years, and the remaining surveys include people aged 40–74 years.

HIC=high-income country. LIC=low-income country. MIC=middle-income country.

Figure 4. Scatter plot of individual-level risk of fatal and non-fatal cardiovascular disease predicted using the office-based versus laboratory-based model in people aged 40–74 years in the Chinese Health and Nutrition Survey 2009 by diabetes status

Red lines show 20% risk. China is shown as an example; all other scatter plots are provided in the appendix pp 389–95. CVD=cardiovascular disease.

10-year CVD risk threshold for high risk		≥10%			≥20%		
Country	Sex	Population at high risk per laboratory-based risk score (%)	Those at high risk identified by the office-based score (%)	Range of office-based risk to refer to laboratory (% of the population in the risk range to detect 95% of high risk)	Population at high risk per laboratory-based risk score (%)	Those at high risk identified by the office-based score (%)	Range of office-based risk to refer to laboratory (% of the population in the risk range to detect 95% of high risk)
Spain (HIC)	Men	24.0%	72.2%	6 to <10 (29.5%)	3.2%	40.7%	11 to <20 (16.0%)
	Women	9.0%	63.5%	5 to <10 (16.4%)	1.7%	24.5%	10 to <20 (7.4%)
South Korea (HIC)	Men	14.9%	66.4%	5 to <10 (30.9%)	1.6%	24.2%	7 to <20 (22.7%)
	Women	8.2%	71.0%	4 to <10 (13.9%)	2.1%	20.1%	10 to <20 (7.6%)
Czech Republic (HIC)	Men	41.7%	82.1%	7 to <10 (19.5%)	9.9%	41.2%	11 to <20 (28.5%)
	Women	14.9%	57.4%	4 to <10 (35.5%)	3.1%	30.0%	8 to <20 (17.3%)
USA (HIC)	Men	28.6%	69.1%	6 to <10 (40.6%)	4.7%	45.1%	9 to <20 (32.3%)
	Women	13.4%	36.4%	3 to <10 (61.1%)	1.7%	7.2%	9 to <20 (10.0%)
China (MIC)	Men	47.2%	87.7%	7 to <10 (11.5%)	22.5%	83.0%	13 to <20 (14.2%)
	Women	38.6%	87.6%	6 to <10 (16.6%)	18.6%	74.9%	9 to <20 (23.7%)
Mexico (MIC)	Men	29.0%	69.1%	6 to <10 (27.0%)	7.5%	48.7%	6 to <20 (47.6%)
	Women	19.5%	67.6%	4 to <10 (31.3%)	6.9%	39.8%	8 to <20 (20.6%)
Iran (MIC)	Men	44.3%	86.5%	8 to <10 (16.7%)	12.6%	54.6%	11 to <20 (32.5%)
	Women	29.7%	75.9%	4 to <10 (34.1%)	10.9%	33.1%	8 to <20 (34.4%)
Jamaica (MIC)	Men	30.4%	85.7%	8 to <10 (10.5%)	8.0%	64.5%	12 to <20 (16.7%)
	Women	21.6%	71.6%	5 to <10 (19.9%)	6.9%	32.5%	6 to <20 (30.4%)
Uganda (LIC)	Men	11.8%	79.4%	7 to <10 (13.9%)	1.1%	37.9%	11 to <20 (10.7%)
	Women	8.9%	88.3%	6 to <10 (12.2%)	2.0%	67.3%	5 to <20 (28.5%)
Cambodia (LIC)	Men	46.1%	90.7%	8 to <10 (13.9%)	9.4%	73.0%	11 to <20 (31.4%)
	Women	31.8%	86.1%	6 to <10 (25.1%)	9.5%	61.6%	6 to <20 (49.7%)

Percentage of those at high risk identified by the office-based score

Proportion of population in the risk range for laboratory testing

≥90%
 ≥80 to <90%
 ≥70 to <80%
 >70%

<10%
 ≥10 to <25%
 ≥25 to <50%
 >50%

Figure 5. Assessment of a two-stage strategy to identify individuals at high risk of fatal and non-fatal cardiovascular disease in ten countries with a recent national health survey
 Countries are ordered by income (World Bank groups) and increasing diabetes prevalence. The surveys for Cambodia, Czech Republic, Iran, and Uganda include people aged 40–64 years, and the remaining surveys include people aged 40–74 years. CVD=cardiovascular disease. HIC=high-income country. LIC=low-income country. MIC=middle-income country.

Table 1

Coefficients from the Cox proportional hazard models for laboratory-based and office-based risk scores

	Coefficients (log HR [95% CI])		HR (95% CI) [*]
	Main effect	Age interaction term [†]	
Laboratory based [‡]			
Systolic blood pressure (per 10 mm Hg)	0.3070 (0.2298 to 0.3842)	−0.0022 (−0.0034 to −0.0011)	1.18 (1.16 to 1.19)
Total cholesterol (per 1 mmol/L)	0.6149 (0.4631 to 0.7667)	−0.0069 (−0.0092 to −0.0045)	1.19 (1.16 to 1.22)
Diabetes	1.4753 (0.9921 to 1.9585)	−0.0132 (−0.0205 to −0.0059)	1.88 (1.71 to 2.06)
Female with diabetes	0.4050 (0.2523 to 0.5578)	..	1.50 (1.29 to 1.75)
Smoker	1.8467 (1.4192 to 2.2741)	−0.0221 (−0.0289 to −0.0152)	1.55 (1.44 to 1.66)
Female smoker	0.3254 (0.1893 to 0.4614)	..	1.38 (1.21 to 1.59)
Office based			
Systolic blood pressure (per 10 mm Hg)	0.3037 (0.2264 to 0.3811)	−0.0021 (−0.0033 to −0.0009)	1.18 (1.17 to 1.20)
BMI (per 5 kg/m ²)	0.3245 (0.1288 to 0.5201)	−0.0030 (−0.0060 to 0.0000)	1.14 (1.11 to 1.17)
Smoker	1.7951 (1.3651 to 2.2251)	−0.0215 (−0.0284 to −0.0146)	1.52 (1.42 to 1.64)
Female smoker	0.3528 (0.2170 to 0.4886)	..	1.42 (1.24 to 1.63)

CVD=cardiovascular disease. HR=hazard ratio.

* HRs for systolic blood pressure, total cholesterol, diabetes, smoking, and BMI are shown at median age of CVD event, which is 64 years in the included cohorts; HRs for smoking and diabetes are for men, and their interaction with sex shows the additional risk among women.

[†] Included because the HRs for effects on CVD decrease with age;^{15–17} therefore, the HR at any age depends on the main effect and interaction terms.

[‡] Previously published data⁹ reported here for comparison between laboratory-based and office-based risk scores.

Laboratory-based and office-based mean 10-year risk of fatal and non-fatal cardiovascular disease and of fatal cardiovascular disease in ten countries with a recent national health survey in people aged 40–64 years

Table 2

	Men		Women	
	Laboratory-based fatal and non-fatal CVD (%)	Office-based fatal and non-fatal CVD (%)	Laboratory-based fatal and non-fatal CVD (%)	Office-based fatal and non-fatal CVD (%)
Cambodia	11.0%	11.2%	9.7%	9.3%
China	9.4%	8.4%	8.0%	7.1%
Czech Republic	10.3%	9.4%	5.6%	5.0%
Iran	11.2%	11.6%	9.0%	8.5%
Jamaica	6.4%	6.1%	4.2%	3.9%
Mexico	7.4%	6.6%	4.6%	4.2%
South Korea	4.6%	4.3%	1.8%	1.5%
Spain	5.9%	5.6%	2.2%	2.0%
Uganda	5.3%	6.0%	4.2%	4.8%
USA	8.5%	7.6%	4.8%	4.2%

Countries are listed in alphabetical order. CVD=cardiovascular disease.