

Association Between Cholesterol Levels, Blood Pressure and Coronary Heart Disease Risk: A Secondary Data Analysis

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Abstract

Coronary heart disease (CHD) remains a major global health concern, with elevated cholesterol and blood pressure contributing significantly to cardiovascular risk. This study investigated the associations between total cholesterol, blood pressure, and recorded 10-year CHD outcomes while evaluating their contributions to risk prediction. A secondary observational analysis was conducted using 4,240 participant records. Descriptive statistics, Welch's t-tests, and Pearson chi-square tests were employed to examine cardiovascular risk factors and CHD occurrence. Multivariable logistic regression estimated adjusted odds ratios (aORs), while five-fold stratified cross-validation assessed predictive discrimination using the area under the receiver operating characteristic curve (AUC). CHD events were recorded in 644 participants (15.2%). Event proportions increased from 10.5% to 17.8% across cholesterol categories and from 8.5% to 30.8% across systolic blood pressure categories. Multivariable analysis identified total cholesterol (aOR = 1.089 per 40 mg/dL), systolic blood pressure (aOR = 1.407 per 20 mmHg), age, male sex, current smoking, and diabetes as significant predictors. The combined cholesterol-systolic blood pressure model achieved an AUC of 0.728, compared with 0.709 for the baseline model. These findings demonstrate that cholesterol and blood pressure provide complementary information for CHD risk assessment. However, the modest improvement in predictive discrimination and absence of external validation warrant cautious interpretation before clinical application.

Keywords: Coronary heart disease; Total cholesterol; Systolic blood pressure; Cardiovascular risk factors; Logistic regression

Introduction

Coronary heart disease (CHD) is still a very important cause of early death and disability globally and has significant clinical and economic impacts. With the development of prevention knowledge, the rising incidence of metabolic abnormalities and modifiable cardiovascular risk factors remains a challenge in preventing these diseases. The burden of cardiovascular diseases (CVDs) is high, and global epidemiological evidence shows that this burden is largely attributable to high blood pressure, dyslipidaemia, diabetes, and behavioural exposures (Roth et al., 2020). The statistics for cardiovascular disease (CVD) continue to highlight the need for effective and readily accessible clinical and preventive measures to identify high-risk individuals (Martin et al., 2025).

High blood pressure is one of the most important modifiable risk factors for cardiovascular morbidity. Large disparities in hypertension prevalence, coverage of hypertension treatment and blood pressure control have been documented at the population level, underscoring ongoing disparities in cardiovascular prevention (NCD Risk Factor Collaboration [NCD-RisC], 2021). High blood pressure (systolic and diastolic) causes vascular damage, endothelial dysfunction, and higher workload on the heart which may promote coronary atherosclerosis. Recent guidelines from Europe call for personalised blood pressure measurement and risk-based treatment to prevent cardiovascular events (McEvoy et al., 2024). Likewise, the revised American recommendations highlight the role of blood pressure classification, risk assessment, and early intervention for patients at risk for cardiovascular disease (Jones et al., 2025).

Other key components of coronary atherosclerotic disease are abnormal cholesterol levels. Hyperlipidaemias increases cholesterol uptake into artery walls, inflammation and the eventual build-up of plaque. There is mechanistic and clinical evidence for the causal role of LDL in atherosclerotic cardiovascular disease (ASCVD) (Borén et al., 2020). European dyslipidaemia guidelines suggest that, along with other cardiovascular risk factors, lipid

assessment should be used to guide preventive management (Mach et al., 2020). More recent recommendations add to the emphasis on comprehensive lipid management and risk-stratified treatment decisions (Mach et al., 2025). However, total cholesterol is a readily available clinical parameter and this association with coronary outcomes is relevant to secondary data analyses.

The risk of cardiovascular disease is being assessed more and more at the individual level taking account of the wider clinical context. Visseren et al., (2021) recommends a comprehensive assessment of demographic, metabolic, behavior and clinical factors for decision making on preventive strategies. Risk prediction algorithms like the SCORE2 show how effective it can be to use several risk factors together to predict future cardiovascular events (SCORE2 Working Group & ESC Cardiovascular Risk Collaboration, 2021). Likewise, the modern cardiovascular risk score systems include cardiovascular, renal, and metabolic features to better assess risk in an individual (Khan et al., 2023). Yet, the proportions of cholesterol and blood pressure can vary by population characteristics, covariate adjustment, and other model specifications.

This study aimed to explore the relationships between total cholesterol, blood pressure, and the documented 10-year CHD outcomes, using secondary observational data. It encompassed demographic and clinical features, categories of cardiovascular risk patterns, and multivariable risk estimation. The goals were to compare participant characteristics by CHD status, examine CHD event rates by cholesterol and blood pressure categories, test the adjusted association with logistic regression, and compare models that include cholesterol and either SBP or DBP.

2. Materials and Methods

2.1. Study Design and Study Population

In this study, quantitative, secondary data analysis by an observational approach was used to explore the relationships between total cholesterol, systolic blood pressure, and diastolic blood pressure with the outcomes of 10-year CHD. A total of 4,240 individual-level observations (demographic, clinical, cardiovascular and metabolic characteristics) were included in the analytical data set. The main outcome was the development of CHD, as recorded over 10 years. The population was divided into CHD participants ($n = 644$) and non-CHD participants ($n = 3,596$) based on the binary outcome indicator. The total number of observations was 4240, and there were no exclusions for any of the variables. Associations between cardiovascular risk factors at baseline and CHD outcome were examined, but no causal inferences were made.

2.2. Study Variables and Operational Definitions

Ten-year incidence of CHD (recorded CHD event = 1, no CHD event = 0) was the primary dependent variable. The following variables were initially analyzed as continuous variables as they were the major explanatory variables: total cholesterol (mg/dL), systolic blood pressure (mmHg), and diastolic blood pressure (mmHg). Total cholesterol was broken down into three categories: <200 , 200 to 239, and ≥ 240 mg/dL for categorical analyses. Systolic blood pressure was classified as <120 , 120–139, 140–159, and ≥ 160 mmHg, while the diastolic blood pressure was classified as <80 , 80–89, and ≥ 90 mmHg. The categories intervals were determined by the lower inclusive and upper exclusive limits.

Other factors analyzed descriptively were age (years), sex, body mass index (BMI; kg/m^2), current tobacco smoking, diabetes, prevalent hypertension, and use of blood pressure medication. Male sex was coded as 1, female as 2, and the outcome of both tests was coded as 0 (absent) or 1 (present). Age, sex, current smoking, diabetes, and BMI were included as adjustment covariates in the multivariable regression models. Comparisons were made with prevalent hypertension and use of blood pressure medication, but these were not entered into any of the reported regression models.

Age was scaled by 10, BMI by 5, total cholesterol by 40, and SBP and DBP by 20 and 10 respectively, for regression interpretation.

2.3. Data Screening and Missing-Data Management

Data screening included checking variables for missingness, coding variables for the outcomes, and checking whether there were observations available for each statistical analysis. No missing values were found for the CHD outcome, age, sex, sx, DBP, current smoking, diabetes or prevalent hypertension. There were missing values for total cholesterol (n = 50), BMI (n = 19), and blood pressure medications (n = 53).

Available observations were used for each variable for descriptive statistics and between group comparisons were made. Thus, analyses of cholesterol included 4,190 participants, analyses of BMI included 4,221, and analyses of blood pressure medication included 4,187 participants. Analyses with variables that had no missing observations included the entire sample (4,240 participants). Among the 4,190 observations for which there were available cholesterol measurements, 635 of the 4,190 had CHD events (15.2%).

Complete case analysis was used for multivariable logistic regression and model-performance analyses because the variables were included for all regression specifications: age, sex, current smoking, diabetes, BMI, total cholesterol, systolic blood pressure, diastolic blood pressure, and CHD outcome. This led to the use of a common analytical sample of 4,172 individuals (625 CHD events and 3,547 non-events). All five regression models used the same set of observations so that the performance of the models can be compared. There was no missing value imputation, or any additional observations were excluded based on clinical outlier thresholds.

2.4. Descriptive Statistics and Bivariate Analysis

Continuous variables were described using averages and standard deviations, and categorical variables were described as counts and percentages. To compare continuous baseline variables between the CHD and non-CHD groups, independent-samples Welch t-tests were used. For categorical variables, Pearson chi-square tests were used to compare baseline characteristics between the CHD and non-CHD groups. Yates continuity correction was not applied in the chi-square tests.

Pearson chi-square tests of independence were used to check the relationships between cholesterol categories and CHD status, as well as between systolic blood pressure and CHD status, and between diastolic blood pressure and CHD status.

The percentage of CHD events in each clinical category was calculated by dividing the number of CHD events by the total number of participants in that category and then multiplying by 100. The estimates for these percentages and their corresponding 95% confidence intervals were calculated using the Wilson score method.

The analysis of cholesterol categories included 4,190 participants, while the analysis of systolic or diastolic blood pressure categories included 4,240 participants.

Bar graphs were used to show the proportions of CHD events based on cholesterol and systolic blood pressure categories. All hypothesis tests were two-sided, and a p-value less than 0.05 was considered statistically significant.

2.5. Multivariable Regression and Model Performance Evaluation

To assess the independent relationship between each cardiovascular risk factor and the risk of developing CHD over 10 years, multivariable binary logistic regression was used to estimate the odds ratios of the risk factors for 10-year CHD event rate. Maximum likelihood was used to estimate regression parameters, with the inclusion of an intercept term. Age, male sex, current smoking, diabetes, BMI, total cholesterol and systolic blood pressure were included in the primary adjusted model. Odds ratios (aOR) were obtained by exponentiating the regression coefficients, and 95% confidence intervals (CIs) were exponentiated coefficient CIs. Two-sided Wald tests were used to assess statistical significance.

Five regression specifications were tested: Model 1 was the baseline model that included age, sex, current smoking, diabetes, and BMI; Model 2 also used baseline covariates plus total cholesterol; Model 3 also used baseline covariates plus systolic BP; Model 4 added both total cholesterol and systolic BP to the baseline covariates; and Model 5 added total cholesterol and diastolic BP to the baseline covariates. Model 4 was selected to be the main adjusted model and Model 5 was used to determine the relationship between the blood pressure measurement of diastolic blood pressure and CHD, separately from the other variables included. Systolic and diastolic blood pressure were not entered at the same time in the blood pressure regression specifications reported.

Model fit was evaluated using the unpenalized maximum-likelihood logistic regression models fit to the full analytical sample, calculating the Akaike information criterion (AIC). The discriminative performance was assessed using five-fold stratified cross-validation with shuffled partitions and with a fixed random seed of 42. Logistic regression with L2 regularization, L-BFGS optimizer and no regularization strength ($C=1$) was used for cross validation. Standardization of predictors was done before estimation of the model within each training fold. The area under the receiver operating characteristic curve (AUC) was obtained by combining out-of-fold predicted probabilities for each model.

The lower the AIC the greater the relative fit of the model and AUC the more accurate the discrimination of the model. ROC curves were made for the baseline model and the main combined cholesterol–systolic blood pressure model. A forest plot was used to present the odds ratios adjusted from the main model with 95% confidence intervals. There was no formal testing of statistical significance of difference between the AUCs of the models and no external model validation was done.

3. Results

3.1. Baseline Characteristics of the Study Population

Among 4,240 participants, 644 (15.19%) had a recorded 10-year CHD event and 3,596 (84.81%) did not. The participants with CHD were older and had higher levels of total cholesterol, SBP, DBP and BMI. The CHD group was also more likely to be male, diabetic, with prevalent hypertension, and taking blood pressure medications. The unadjusted comparison of currently smoking showed no significant difference among the groups (Table 1).

Table 1. Baseline characteristics by recorded 10-year CHD status.

Characteristic	Overall	Non-CHD	CHD	p-value
Age (years)	49.58 ± 8.57	48.76 ± 8.41	54.15 ± 8.01	<0.001
Male, n (%)	1820 (42.9)	1477 (41.1)	343 (53.3)	<0.001
Total cholesterol (mg/dL)	236.70 ± 44.59	235.15 ± 43.77	245.39 ± 48.08	<0.001
Systolic BP (mmHg)	132.35 ± 22.03	130.34 ± 20.45	143.62 ± 26.69	<0.001
Diastolic BP (mmHg)	82.90 ± 11.91	82.17 ± 11.34	86.98 ± 14.03	<0.001
BMI (kg/m ²)	25.80 ± 4.08	25.67 ± 3.98	26.53 ± 4.52	<0.001
Current smoker, n (%)	2095 (49.4)	1762 (49.0)	333 (51.7)	0.205
Diabetes, n (%)	109 (2.6)	69 (1.9)	40 (6.2)	<0.001
Prevalent hypertension, n (%)	1317 (31.1)	992 (27.6)	325 (50.5)	<0.001
Blood pressure medication, n (%)	124 (3.0)	83 (2.3)	41 (6.5)	<0.001

3.2. Association Between Total Cholesterol Levels and Coronary Heart Disease

The proportion of CHD events observed increased with higher cholesterol levels, ranging from 10.47% in the <200 mg/dL level to 14.48% in the 200-239 mg/dL level to 17.76% in the ≥240 mg/dL level (Table 2). Association was found to be statistically significant ($\chi^2 = 24.62$, $p < 0.001$). This gradient is shown in Figure 1.

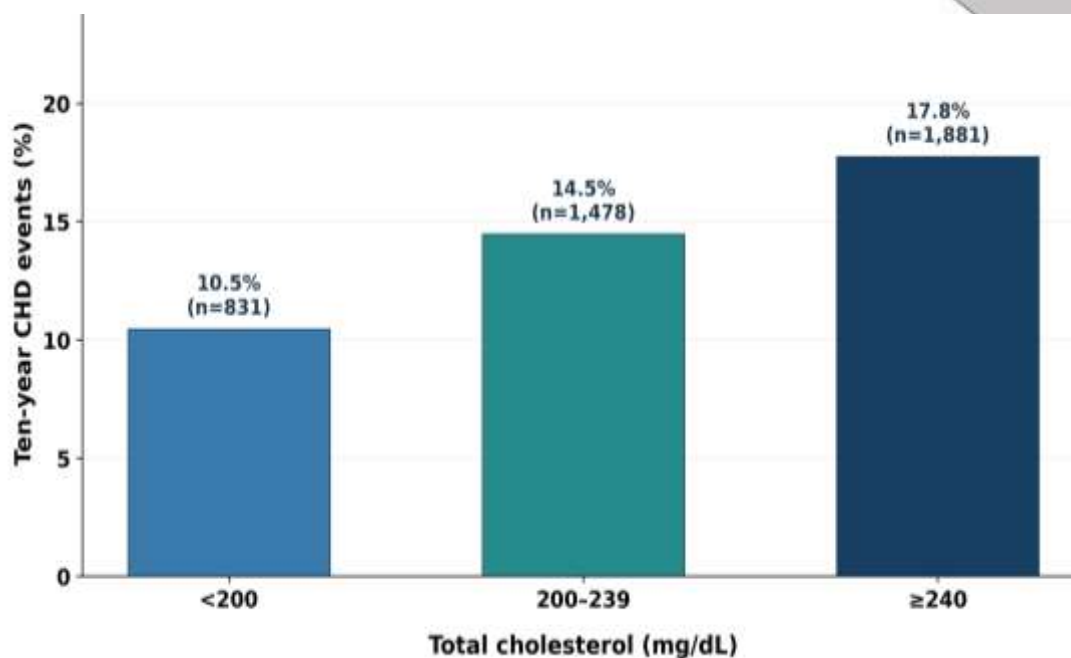


Figure 1. Observed CHD event proportions by total cholesterol category

3.3. Association Between Blood Pressure and Coronary Heart Disease

Systolic BP showed a significant gradient relationship with CHD with the proportion of events increasing as SBP increased, 8.52%, 13.00%, 21.09% and 30.75% ($\chi^2 = 162.06$, $p < 0.001$). The same association was seen for the diastolic BP, which had event proportions of 11.22%, 13.35% and 24.03% across increasing categories ($\chi^2 = 88.73$, $p < 0.001$). The estimates at the category level are shown in Table 2; the systolic pattern is shown in Figure 2.

Table 2. Recorded CHD events by cholesterol and blood pressure categories.

Measure / category	N	CHD events	Event %	95% CI
Cholesterol <200	831	87	10.47	8.57–12.74
Cholesterol 200–239	1478	214	14.48	12.78–16.37
Cholesterol ≥240	1881	334	17.76	16.10–19.55
SBP <120	1279	109	8.52	7.11–10.18
SBP 120–139	1677	218	13.00	11.47–14.69
SBP 140–159	806	170	21.09	18.42–24.04
SBP ≥160	478	147	30.75	26.78–35.03
DBP <80	1666	187	11.22	9.80–12.83
DBP 80–89	1513	202	13.35	11.73–15.16
DBP ≥90	1061	255	24.03	21.56–26.70

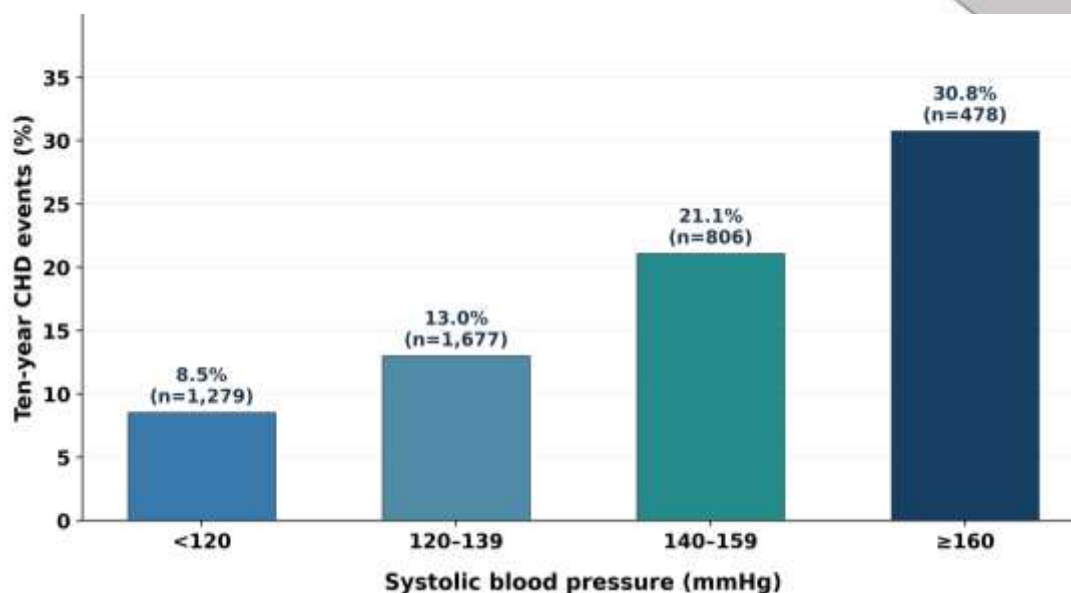


Figure 2. Observed CHD event proportions by systolic blood pressure category

3.4. Multivariable Logistic Regression Analysis of Coronary Heart Disease Risk Factors

There were 4,172 subjects with 625 CHD events in the primary complete case. Following covariate adjustment, the factors age, male sex, current smoking, diabetes, total cholesterol, and systolic BP remained independently associated with CHD, while BMI was not statistically significant (Table 3). Total cholesterol was associated with 8.9% higher odds per 40 mg/dL (aOR = 1.089, 95% CI: 1.005–1.181), while systolic BP was associated with 40.7% higher odds per 20 mmHg (aOR = 1.407, 95% CI: 1.295–1.529). The adjusted ORs and confidence intervals are shown in Figure 3. The other model showed an association of diastolic BP with CHD (aOR = 1.260 per 10 mmHg, 95% CI: 1.168–1.359).

Table 3. Adjusted logistic regression associations with recorded CHD outcomes (n = 4,172).

Predictor (increment)	aOR	95% CI	p-value
Age (10 years)	1.911	1.698–2.151	<0.001
Male sex	1.856	1.537–2.243	<0.001
Current smoking	1.509	1.244–1.830	<0.001
Diabetes	1.998	1.294–3.086	0.002
BMI (5 kg/m ²)	1.046	0.934–1.172	0.438
Total cholesterol (40 mg/dL)	1.089	1.005–1.181	0.037

Systolic BP (20 mmHg)	1.407	1.295–1.529	<0.001
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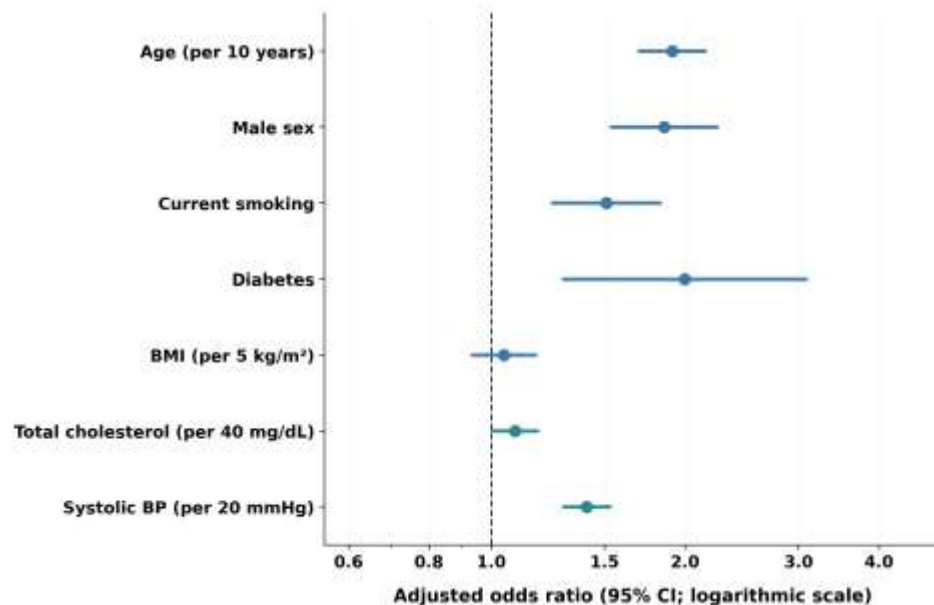


Figure 3. Adjusted odds ratios with 95% confidence intervals in the primary model

3.5. Comparative Model Performance and Discriminative Ability

The addition of cholesterol to the baseline model resulted in a modest increase in discrimination with the addition of systolic BP producing a greater increase in discrimination. The model that included both cholesterol and systolic BP had the smallest AIC (3167.53) and the largest cross-validated AUC (0.728). The alternative cholesterol–diastolic BP model was the next with an AUC of 0.720 (Table 4). Cross-validated ROC curves of the baseline model and primary combined model are compared in Figure. 4. These results are obtained by internal cross validation and not external.

Table 4. Model fit and cross-validated discrimination (common n = 4,172). Baseline: age, male sex, smoking, diabetes, BMI.

Model	Predictors added to baseline	AIC	Cross-validated AUC
1	None	3236.586	0.709
2	Total cholesterol	3230.703	0.711
3	Systolic BP	3169.824	0.726
4	Total cholesterol +	3167.533	0.728

	systolic BP		
5	Total cholesterol + diastolic BP	3197.397	0.720

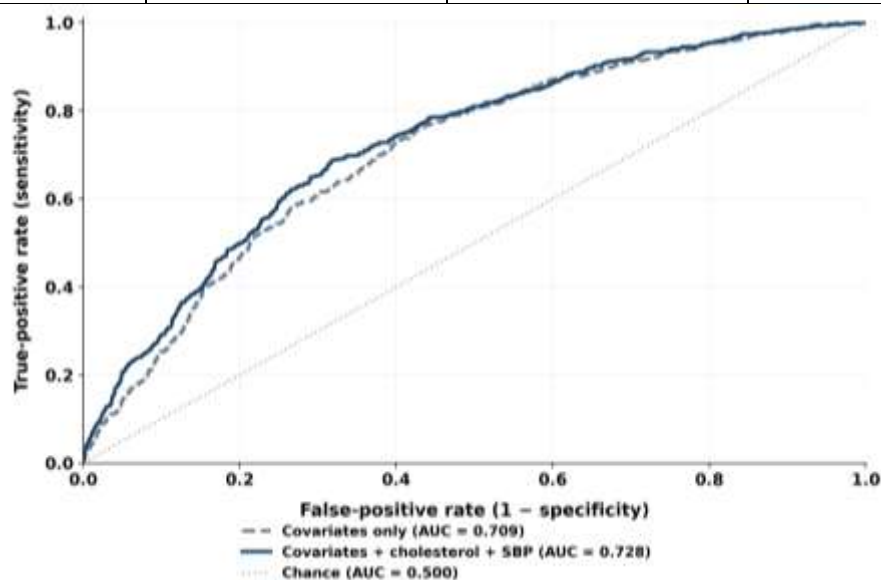


Figure 4. Out-of-fold ROC curves for the baseline and combined models

4. Discussion

The current study examined the relationships among total cholesterol BP and measured 10-year CHD events in 4,240 people. Fifteen percent of the study population (15.2%) had a CHD event. Generally, participants with CHD had higher levels of cholesterol, SBP, DBP, age and prevalence of diabetes compared to those without CHD. The results suggest that several demographic and clinical factors were related to cardiovascular risk, with the contribution of individual factors being different and varying upon multivariable adjustment.

Total cholesterol categories were found to be related to increasingly higher proportions of observed CHD events, ranging from 10.5% for those with cholesterol < 200 mg/dL, to 17.8% for those with cholesterol $\geq$ 240 mg/dL. The adjusted association was still significant, albeit modest (aOR = 1.089 per 40 mg/dl). This is in line with the evidence that suggests that high atherogenic cholesterol levels for an extended period of time are associated with subsequent cardiovascular events (Zhang et al., 2021). Cardiovascular risk throughout adulthood has been further established by longitudinal studies which indicate that exposure to cholesterol throughout life is relevant in the interpretation of the risk (Domanski et al., 2020). The results of the present analysis, however, do not provide direct evidence for associations related to LDL because the analyses were conducted on total cholesterol and not on the individual lipoprotein fractions.

The BP showed a very strong association with CHD. The percentages of observed events rose with each increase in systolic BP, from 8.5% for those with the lowest BP to 30.8% for those with the highest BP (at 160 mmHg or higher). Each increment of 20 mmHg in SBP was found to be associated with an increased odds for CHD in the primary adjusted model (aOR = 1.407). The findings are in line with the study that concluded SBP is an important cardiovascular risk marker in all age groups (Wang et al., 2023). Individual participant-level meta-analysis also confirms BP lowering to have beneficial cardiovascular effects in various baseline BP group (Rahimi et al., 2021a). In

the alternative model, both DBP and DBP increases per 10 mmHg were independently associated with CHD (aOR = 1.260 per 10 mmHg). Their relative importance should be taken with caution however, as they were analysed in distinct regression specifications.

After controlling for BMI, age, male sex, current smoking and diabetes were also independently associated with CHD. The association is in line with a sustained focus on BP control in cardiovascular prevention in people with and without diabetes (Nazarzadeh et al., 2022). Modern guidelines also stress the importance of managing all cardiovascular risk factors in people with diabetes (Marx et al., 2023). Interpretation of associations between BP and cardiovascular outcomes should be tailored to the individual as there are age-related differences in cardiovascular risk (Rahimi et al., 2021b).

The inclusion of cholesterol and systolic BP was shown to increase discrimination compared to the baseline model by model comparisons with a cross-validated AUC of 0.728. This was, however, quite limited, indicating that further clinical risk factors might be required for better risk stratification. In modern cardiovascular prediction studies, the use of multiple domains of cardiovascular risk is stressed when building prediction equations (Khan et al., 2024). External validation studies also show that predictive performance needs to be assessed for different populations prior to clinical use (Scheuermann et al., 2024). Also, there are recent methodological discussions regarding calibration, population applicability and clinical utility of risk-prediction models when making interpretations (Garba et al., 2024). The present models were not assessed in an external setting and should not be viewed as being clinically ready.

The results generally validate the importance of cholesterol and BP measurements in the assessment of risk for CHD. There were several important limitations, such as the observational design, exclusions due to missing data, lack of detailed lipid fractions, and limited clinical predictors available. Therefore, the reported relationships should be considered as non-causal and should be investigated further with external validations.

5. Conclusion

In the current study, there were marked associations between total cholesterol and BP and registered 10-year CHD outcome in a secondary analysis of 4,240 individuals. The levels of cholesterol and systolic and diastolic BP were found to be important factors in cardiovascular risk assessment, with higher values corresponding to increasing proportions of CHD events. This was especially true of systolic BP, which showed a strong association, with proportions of CHD events climbing significantly from one category of BP to the next. Multiple logistic regression revealed that after controlling for demographic, behavioural and metabolic factors, total cholesterol, and systolic BP were still independently associated with CHD. These were followed by age, male sex, current smoking and diabetes, which also were significant predictors, while BMI had no statistically significant independent association. Adding cholesterol and systolic BP showed modest improvements in predictive discrimination over the baseline model, as suggested by the comparative model evaluation. The results confirm the overall evaluation of lipid profile and BP level and established cardiovascular risk factors instead of separate clinical parameters. However, the observational study design, limited clinical data, and lack of external validation restrict causal conclusions and immediate clinical use. Additional lipid parameters, more representative populations, longer follow-up periods, and external validation should be included in further studies to enhance risk prediction accuracy. The results are generally consistent with the value of comprehensive cardiovascular risk assessment to identify those who could benefit from specific preventive actions.

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