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Burden of newly diagnosed hypertension and potential 10-year cardiovascular risk in Burundi: A Bayesian logistic regression and Framingham score-based study

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Burden of newly diagnosed hypertension and potential 10-year cardiovascular risk in Burundi: A Bayesian logistic regression and Framingham score-based study

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Abstract

Introduction: Arterial hypertension is a major global public health concern. In Burundi, it coexists with other non-communicable and communicable diseases, contributing to a complex and evolving health burden that poses substantial challenges for prevention, diagnosis, and management. We aimed to assess the burden of newly diagnosed hypertension, identify associated risk factors, and assess 10-year cardiovascular risk among hypertensive and non-hypertensive patients.

Methods: We conducted a cross-sectional study of 714 patients admitted to Kamenge Teaching Hospital between January 2018 and January 2023. Retrospective data were extracted from medical records. Bayesian belief updating was used to estimate the prevalence of newly diagnosed hypertension, while Bayesian logistic regression with bootstrapping was used to identify associated risk factors. Bayesian linear models were used to assess the association between diastolic blood pressure and cardiovascular risk level. Potential 10-year cardiovascular risk was estimated using the Canadian Framingham Risk Score.

Results: The prevalence of newly diagnosed hypertension was 16.9% (95% CrI: 14.2–19.7%). Higher prevalence was observed among women (18.0%), patients aged 40–59 years (21.3%) and ≥60 years (33.9%), those with higher educational attainment (up to 28.9%), and individuals who were overweight or obese or had a family history of hypertension. Predictors of hypertension included age ≥40 years, tobacco use, education level, and excess weight. Moderate or severe 10-year cardiovascular risk was present in 24.9% of patients, with more than 60% of patients with hypertension classified as high risk. Diastolic blood pressure was positively associated with cardiovascular risk among both hypertensive and non-hypertensive patients.

Conclusion: Newly diagnosed hypertension and its association with elevated cardiovascular risk highlight potential missed opportunities for early diagnosis and prevention. Targeted screening and management of modifiable risk factors may help reduce cardiovascular risk in Burundi.

Keywords*: Newly Diagnosed Hypertension, Cardiovascular Risk, Framingham Risk Score, Bayesian Modelling, Burundi*

Research in context

Evidence before this study

Africa is experiencing an epidemiological transition marked by a rapid increase of non-communicable diseases with cardiovascular diseases emerging as a substantial public health challenge in the region. We searched PubMed and Google scholar for published papers (in English) between Jan 1, 2000, and Dec 31, 2022, using the terms ("hypertension" or "high blood pressure") and ("Burundi" or "East Africa") and ("risk factors" or "cardiovascular risk") and "model". Few studies reported the prevalence of newly diagnosed hypertension in Burundi or assessed 10-year cardiovascular risk among hypertensive and non-hypertensive patients. Existing evidence mainly described cross-sectional prevalence or hospital-based data, with limited evaluation of cardiovascular risk stratification. No studies comprehensively combined newly diagnosed hypertension, associated predictors, and 10-year cardiovascular risk in this setting.

Added value of this study

We assessed newly diagnosed hypertension in 714 patients admitted to a tertiary hospital in Burundi and identified risk factors. We also quantified 10-year cardiovascular risk using the Canadian Framingham Risk Score, showing that 25% of patients have a moderate to severe risk of cardiovascular risk (CVD) with over 60% of hypertensive patients at high risk. Our risk assessment in a low-resource setting provides actionable insights for targeted prevention.

Implications of all the available evidence

The relatively high prevalence of newly diagnosed hypertension and its strong association with cardiovascular risk highlight missed opportunities for early detection and prevention. Systematic screening and interventions targeting modifiable risk factors could reduce cardiovascular disease burden. These findings support national strategies to strengthen non-communicable disease prevention in Burundi and other low-resource settings.

1.Introduction

Arterial hypertension is a major public health threat[1, 2], contributing to the growing burden of cardiovascular diseases (CVDs) [1, 3, 4]. In sub-Saharan Africa (SSA), deaths due to CVD have increased by more than half over the past three decades, and now account for over a million deaths per year in the region[5]. Although Africa has a predominantly young population, today's young adults will progressively enter older age, potentially increasing the future burden of cardiovascular disease[6]. The rising burden of NCDs among young adults therefore highlights the need for early prevention and risk reduction. This broader regional context is particularly relevant to Burundi, where hypertension is already prevalent, yet evidence on cardiovascular risk among newly diagnosed patients remains limited.

In Burundi, the age-standardized prevalence of hypertension among adults aged 30–79 years exceeds the global average, with women exhibiting higher rates than men[7]. Burundi has a high burden of both communicable and NCDs, with the latter making up 37% of deaths in 2019. This coexistence creates a complex situation that is difficult to address, contributing to a persistently high incidence of cardiovascular diseases, with more than 300 cases per 100,000 inhabitants since 2017[8].

The 2025 Global report on hypertension highlights the urgent need to scale up detection, treatment, and control of hypertension, especially at the primary health care level[9, 10]. However, two-thirds of individuals with hypertension are undiagnosed, untreated, or inadequately treated [11]. The delay in early diagnosis and/or treatment of hypertension leads to several complications [12, 13]. These complications are among leading causes of death worldwide [14, 15]. By 2030 , Arterial hypertension and other non-communicable diseases are expected to surpass infectious diseases as the leading causes of death in the African Region [16], with serious socio-economic consequences.

Between 2011 and 2025, the cumulative loss in productivity attributable to non-communicable diseases (NCDs), including hypertension, was estimated at US$7.28 trillion in low- and middle-income countries (LMICs), equivalent to approximately US$500 billion annually[17]. Cardiovascular diseases, including hypertension, accounted for nearly half of this economic burden[18]. Beyond substantial economic costs associated with premature mortality, productivity losses, and healthcare expenditure[19] , Burundi like other LMICs faces a major challenge of early diagnosis, timely treatment and effective control of hypertension[20, 21]. These challenges are particularly relevant in Burundi, where efforts to address the growing burden of NCDs have been made, but important gaps remain.

Despite implemented NCD policies, progress has been limited in several key areas, including tobacco media campaigns, restrictions on alcohol advertising, salt-reduction policies, and physical activity awareness[7]. A previous study conducted on 20 297 patients in rural areas of Burundi found hypertension as main CVD risk factors followed by diabetes and alcohol abuse[22].Effective hypertension control could prevent around 26,000 deaths by 2040[7]. However, the country lacks recent national surveys on hypertension and does not have a functioning system for routinely generating cause-specific mortality data.

Although Global Burden of Disease studies provides independent estimates of the prevalence, mortality, and disability due to high blood pressure worldwide [23], studies aiming to understand the epidemiology of newly diagnosed high blood pressure, associated factors, and related medium and long term risk of cardiovascular morbidity in the in the context of Burundi are lacking, which has motivated the conduct of this study. Indeed, effective control of newly

diagnosed high blood pressure may need to involve a comprehensive prevention strategy at both the individual and population levels[15]. In addition to effective clinical interventions to delay the progression of high blood pressure toward cardiovascular complications, it is essential to have prognostic models that can identify patients at high risk of hypertension or cardiovascular morbidity[24].This underscores the importance of the present study.

This study aims to assess the extent of newly diagnosed high blood pressure and predict the risk of cardiovascular morbidity over a 10-year period among patients hospitalized in the internal medicine department of the Kamenge Teaching Hospital over a 5-year period. Specifically, this study aims to determine the prevalence of newly diagnosed and treated hypertensive patients, to identify associated factors to hypertension and to evaluate the cardiovascular disease morbidity risk on a 10-years horizon.

Evidence from this study could serve as a foundation for effective planning for Burundian NCD program and formulate strategies to reduce hypertension and the associated cardiovascular morbidity. This study aligns with one the global objectives for non-communicable diseases, which aims to reduce the burden of high blood pressure by 33% by 2030 [25-29], the Global NCD Compact 2020–2030 aiming to accelerate progress on the prevention control and of NCD and Burundi NCD strategic plan.

2-0. Methods

2-1. Study design and sampling

We conducted a retrospective cross-sectional study at Kemenge Teaching Hospital, from patients' medical records, using a structured data extraction form developed by study team specifically for this study (**S1 File)**. The form was not administered to patients but was used to extract information routinely recorded in their medical records. It was designed to extract socio-demographic, clinical, anthropometric, laboratory as well as variables required to calculate the Framingham risk score. The form's content was defined from the variables required to calculate the Framingham risk score[30, 31] and from established risk factors for hypertension [32-35]. The 2018-2023 period was targeted due the significant increase of CVDs incidence rate in Burundi since 2016[8]. **S1 Figure** show the trend of cardiovascular diseases' incidence rate per 100 000 habitants between 2016 and 2022 in Burundi.

We included all patients admitted in internal medicine between January 2018 and January 2023 (Regardless of the reason for consultation and/or hospitalization) for whom all clinical and biological elements of the Framingham score were available on their medical records. Patients were excluded if they had known cardiovascular disease, pre-existing known and treated hypertension treatment before admission to Kamenge Teaching Hospital, or incomplete clinical or biological information required to calculate the Framingham risk score. Indeed, patients not on treatment prior to admission were prioritized in this study, as uncontrolled hypertension places individuals at high risk for the development of cardiovascular disease. This risk is further compounded by the potential for cardiovascular morbidity associated with late-stage diagnosis, often occurring at the stage of complications.

In this study, we considered the admission in the internal medicine of Kamenge Teaching Hospital to be independent from one patient to another. All patients in internal medicine service had therefore the same chance to be selected. The minimal sample size was calculated as follows:

$$n = \frac{\chi^2 \times p \times (1-p) \times \pi}{\chi^2 \times (1-p) + \alpha^2 \times (\pi - 1)} \quad (1)$$

Where χ^2 is the Chi square test (3.841) at 1 degree of freedom and 95% of confidence, π is population size (8960), n is the minimal sample size, p is the prevalence of hypertension and α , the error threshold (5%). Being unknown, the prevalence of hypertension was by default set at 0.5. The minimum required sample size was therefore 368 patients. A total of 714 eligible patients were included, exceeding the minimum required sample size and providing greater precision for the study estimates and statistical analyses.

2-4. Primary and secondary outcome measures

The primary outcome is newly diagnosed hypertension among patients admitted to Kamenge Teaching Hospital between January 2018 and January 2023, expressed as the prevalence of hypertension in the study population. Secondary outcomes included factors associated with newly diagnosed hypertension, 10-year cardiovascular risk estimated using the Canadian Framingham Risk Score, and the association between diastolic blood pressure and 10-year cardiovascular risk among hypertensive and non-hypertensive patients.

2-5. Study variables

Hypertension was defined based on the blood pressure measurement obtained after three successive measurements at initial assessment before treatment initiation. Patients were classified as newly hypertensive if systolic blood pressure (SBP) was ≥140 mmHg and/or diastolic blood pressure (DBP) was ≥90 mmHg[36] , with a first-time diagnosis and antihypertensive treatment initiated during the hospitalisation episode at Kamenge Teaching Hospital[37]. Newly diagnosed hypertension was specifically considered in this study because hypertension may remain undetected until patients present with complications[12, 13]. In addition, untreated hypertension is associated with an increased risk of cardiovascular morbidity and mortality [38].

Potential risk factors for hypertension and cardiovascular morbidity were selected based on their established or hypothesised associations with these outcomes and supported by existing scientific evidence[32-35].These factors include sex (male, female), place of residence (urban, rural), education level (primary or less, secondary, university), alcohol consumption (yes/no), tobacco use (yes/no), chronic kidney disease (yes/no), diabetes (yes/no), BMI, and family history of hypertension (yes/no). BMI was calculated by dividing weight in kilograms by the square of height in meters and categorized into four groups: underweight (BMI < 18.5 kg/m²), normal weight (18.5 kg/m² ≤ BMI ≤ 24.9 kg/m²), overweight (25.0 kg/m² ≤ BMI ≤ 29.9 kg/m²), and obesity (BMI ≥ 30 kg/m²)[39]. In addition to the aforementioned factors, this study incorporated additional parameters from the Framingham Score (**S2 Figure)**, including systolic blood pressure (mm Hg), total cholesterol level (mmol/L), and high-density lipoprotein (HDL) cholesterol level (mmol/L).

2-6. Data analysis

Data was analysed in several steps combining descriptive analysis, Bayesian logic regression and Bayesian Linear regressions. Descriptive analysis was conducted by presenting patient characteristics versus their hypertensive status and CVD risk level in the form of tables or graphs. A Bayesian logistic regression model was fitted using the rstanarm package in R, with newly diagnosed hypertension as the binary outcome. The model included educational level, smoking status, age category, body mass index category, chronic kidney disease, known diabetes, and family history of hypertension as predictors. A weakly informative Normal prior with mean 0 and standard deviation 10 was assigned to all regression coefficients, including the intercept. Four Markov chain Monte Carlo chains were run for 2,000 iterations each, with

the first 1,000 iterations of each chain discarded as warm-up. Predictive power of the final model, and prediction of the probability of hypertension occurrence

2-6-1. Bayesian belief update evidence based

Because some patients had missing variables required to calculate the Framingham risk score, the prevalence of newly diagnosed hypertension among patients with complete data was estimated using a Bayesian beta-binomial model[40]**.** This approach provided a full posterior distribution of the prevalence rather than a single point estimate, allowing uncertainty around the prevalence estimate to be quantified through the corresponding 95% credible interval. Hypertension was a binomial outcome (either hypertensive or not hypertensive). A beta prior, $\beta eta(\alpha,\gamma)$,was assigned to the prevalence parameter p, representing a uniform prior distribution in the absence of informative prior about the prevalence at the national level $p \in [0,1]$. The likelihood function was specified as Binomial distribution because we have a fixed sample size n and a number of successes (new hypertensive individuals). The posterior belief is $\beta eta(\tilde{\alpha},\tilde{\gamma})$ where $\tilde{\alpha}=\alpha+x$ and $\tilde{\gamma}=\gamma+n-x$ .The true prevalence was given by the following formula:

$$p(\theta/y)=\frac{p(y/\theta)\times p(\theta)}{p(y)} \tag{2}$$

Where θ is the parameter (true prevalence of hypertension), y is data (our data sample), $p(\theta/y)$ is a posterior, $p(y/\theta)$ is likelihood, $p(\theta)$ is the prior and the probability of the data is defined as:

$$p(y)=\int p\left(\frac{y}{\theta}\right)\times p(\theta)\,d\theta \tag{3}$$

The true prevalence is equivalent to the posterior mean:

$$Posterior\ mean=\frac{\alpha}{\alpha+\gamma}\rightarrow\frac{\tilde{\alpha}}{\tilde{\alpha}+\tilde{\gamma}}=\frac{\alpha+x}{\alpha+\gamma+x} \tag{4}$$

Using Bayesian updating, we combined the prior and likelihood to calculate the posterior $\beta eta(\alpha+x,\gamma+n-x)$,where x success of n trials is the evidence and posterior distribution of the prevalence p is binomial:

$$y\sim(n,p) \tag{5}$$

After running the Bayesian model, we sampled from the posterior distribution of p, posterior mean which gives us an estimate of the true prevalence of hypertension in the population. We also checked the convergence using the Gelman-Rubin diagnostic[41].

2-6-2. Bayesian logistic regression

Univariate correlations were performed to assess the association between each predictor and the outcome variable and were further examined using univariate Bayesian logistic regression models. Bayesian logistic regression allowed incorporation of prior distributions for model parameters, providing a flexible framework for estimating uncertainty. Four Markov chain Monte Carlo (MCMC) chains, each with 4 000 iterations, were used to obtain posterior distributions. For each variable, we calculated the crude odds ratio (cOR) with its 95% credible interval. Variables associated with the outcome at p<0·20 in the univariate analysis were entered into a multivariable Bayesian model, together with variables whose posterior

probability do not exceed 0·25 and judged clinically relevant. The equation used to estimate risk in the Bayesian logistic regression model was as follow:

$$\pi_i = E(Y_i/X) = \frac{e^{\beta_o+\beta_1 X_{i1}+\beta_2 X_{i2}+\cdots+\beta_n X_{in}}}{1+e^{\beta_o+\beta_1 X_{i1}+\beta_2 X_{i2}+\cdots+\beta_n X_{in}}} \quad (5)$$

The Bayesian Logistic Regression with multiple predictors become as detailed below:

$$\text{logit}[\theta] = \text{logit}\left[\frac{\theta}{1-\theta}\right] = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (6)$$

Where θ is the probability of hypertension occurrence, β_o is the intercept, β_1, β_2,.., β_n are the coefficients; and $X_1, X_2,\ldots, X_n$ are the independent variables. Instead of estimating fixed values for the coefficients, we estimated their posterior distributions using prior distributions and observed data. From these models, we developed a multivariable model. Variable selection was guided by examination of the posterior coefficient distributions, with iterative updating to retain only predictors with meaningful posterior support. This selection was further informed by projection predictive variable selection, as described by Piironen, Paasiniemi, and Vehtari (2020)[42].

Bayesian Logistic regression was used because Markov chain Monte Carlo (MCMC) algorithms provide posterior distribution estimates without relying on large sample sizes, except for the number of iterations, which can be easily increased[43]. Additionally, Bayesian methods are more flexible, allowing the incorporation of external information through informative priors when available, or the use of noninformative priors. Adjusted odds ratios (a**ORs**) with 95% credible intervals were reported for all predictors.

2-6-3. Model evaluation

Model fit was evaluated using leave-one-out cross-validation (LOO-CV) via the *loo* package, with moment matching applied for observations with high Pareto-k values. We examined calibration of the posterior and LOO predictive probabilities compared to observed binned event rates. We sorted the predicted probabilities in ascending order, bin the corresponding binary observations and plotted the mean and uncertainty interval based on binomial distribution. We also used the new approach for assessing calibration (or reliability as they call it) that uses nonparametric isotonic regression and the pool-adjacent-violators (PAV) algorithm to estimate conditional event probabilities (CEPs) with automated choice of bins[44].

2-6-4. Evaluation of the 10-year cardiovascular risk

The 10-year cardiovascular disease (CVD) risk was estimated using the Framingham Risk Score based on age, sex, total cholesterol (in mmol/l), HDL cholesterol (in mmol/l), systolic blood pressure ((in mm Hg), antihypertensive treatment, and smoking status. The score was originally developed and validated in populations outside sub-Saharan Africa and has not been specifically validated in Burundi. We classified participants according to the standard categories as low risk (<10%), intermediate risk (10–19%), and high risk (≥20%) [30, 31]. This score predicts cardiovascular morbidity over a 10-year period. We evaluated the 10-year cardiovascular morbidity risk in both newly and non-newly diagnosed hypertensive patients, meaning all 714 patients included in the study. This evaluation was based on all the elements of the Framingham score and was subsequently categorized into three risk levels. A comparative analysis was conducted between hypertensive and non-hypertensive patients.

Data processing, statistical analysis, and data visualization were performed using R and RStudio. Data manipulation and visualization were conducted using the dplyr and ggplot2 packages, respectively, while Bayesian regression analyses were performed using the rstanarm package. All analyses were conducted using R version 3.5.0[45].

2.7. Ethical considerations

The study received research authorization from the Institutional Review Board (IRB) of Kamenge Teaching Hospital (**Ref: 2023DGCHUK.835/11.5**), which permitted access to patients' medical records for the purposes of the study. Data were retrospectively extracted from these records. To protect patient confidentiality, all identifying information was removed and replaced with unique study codes before data analysis.

3-0. Results

3-1. Socio-demographic characteristics of patients

In this study, the median age of patients was 43(95% CI :42, 44) years. The average age was 59.8 (95% CI: 56.1-61.9) and 43.8(95% CI: 39.6- 52.4) respectively for newly diagnosed hyp ertensive and treated patients, and no hypertensive patients (**Figure 1**). **Figure 1** shows the ag e-specific distributions of hypertension (A) and cardiovascular disease risk (B)

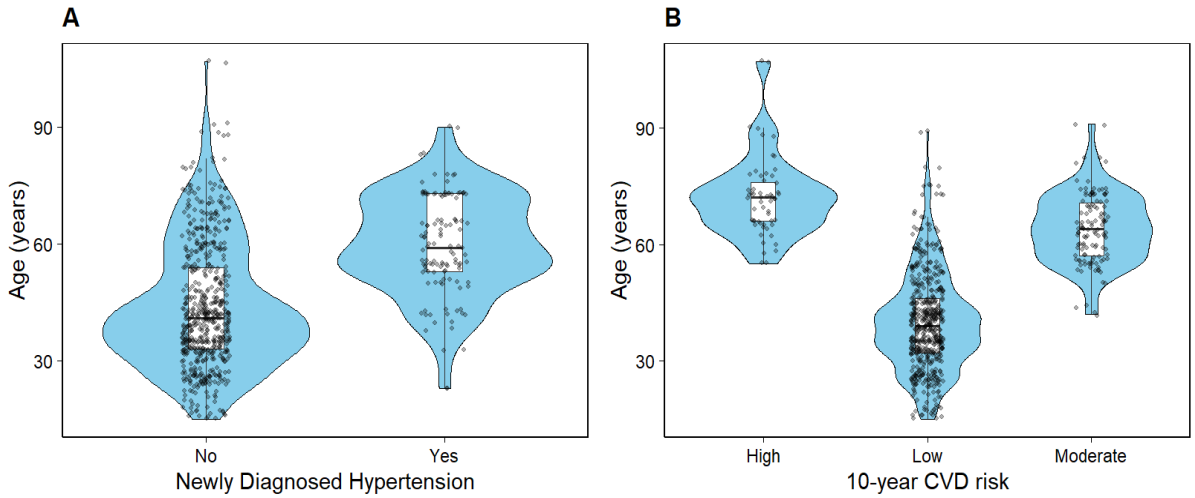


Figure 1. Age-specific distributions of hypertension (A) and cardiovascular disease risk (B)

The male sex accounted for 57.9% of the study population, corresponding to a male-to-female ratio of 1.38. Nearly two-thirds of the patients (60.9%) were aged 40 years or older. Most patients had secondary-level education (46.8%), were married (74.5%), and lived in urban areas (53.4%). The sociodemographic and clinical characteristics of the study population are presented in **Table 1**.

Table 1. Sociodemographic and clinical characteristics of patients according to newly diagnosed hypertension status (N = 714)

Characteristics	Total		Newly diagnosed hypertensive				p^{HTA+}
	N=714	%	HTA-	%	HTA+	(%)	%
Sex							
Female	300	42.1	246	34.5	54	18.0	13.4
Male	414	57.9	348	48.7	66	15.9	11.9
Age (in years)				0.0			

15-39	280	39.2	274	38.4	6	2.1	1.6
40-59	263	36.8	207	29.0	56	21.3	15.9
≥60	171	23.9	113	15.8	58	33.9	25.3
Education level							
Primary or less	276	38.7	247	34.6	29	10.5	7.9
Secondary	334	46.8	273	38.2	61	18.3	13.6
University	104	14.6	74	10.4	30	28.9	21.5
Marital status							
Maried	532	74.5	429	60.1	103	19.4	14.5
Unmaried	182	25.5	165	23.1	17	9.3	6.9
Residence							
Rural	333	46.6	277	38.8	56	16.8	12.6
Urban	381	53.4	317	44.4	64	16.8	12.5
Alcohol							
No	350	49.1	294	41.2	56	16.0	11.9
Yes	364	50.9	300	42.0	64	17.6	13.1
Tobacco							
No	657	92.1	554	77.6	103	15.7	11.7
Yes	57	7.9	40	5.6	17	29.8	22.2
CKF							
No	342	47.9	332	46.5	10	2.9	2.2
Yes	372	52.1	262	36.7	110	29.6	22.1
Diabetes				0.0			
No	553	77.5	499	69.9	54	9.8	7.3
Yes	161	22.5	95	13.3	66	41.0	30.6
Hypertension in family							
No	344	48.2	334	46.8	10	2.9	2.2
Yes	370	51.8	260	36.4	110	29.7	22.2
BMI							
Normal	544	76.2	474	66.4	70	12.9	9.6
Overweight	122	17.1	90	12.6	32	26.2	19.6
Obesity	48	6.7	30	4.2	18	37.5	28.0

CKF: Chronic Kidney Failure, BMI: Body Mass Index, pHTA^{+}: proportion of newly diagnosed hypertensive patients

Among the 714 patients included in the study, 120 had newly diagnosed hypertension, corresponding to a crude proportion of 16.8%. The Bayesian posterior distribution yielded a mean prevalence estimate of 16.9% (95% CrI: 14.2%–19.7%), as shown in **Figure 2.** Gelman-Rubin diagnostic showed the potential scale reduction factor for the MCMC and its upper bound of the 95% credible interval to be respectively 1 and 1.01. This suggests the absence of divergence, a well-mixage in the chains, and MCMC sampling convergence. **Figure 2** shows the prevalence and density of newly diagnosed hypertension.

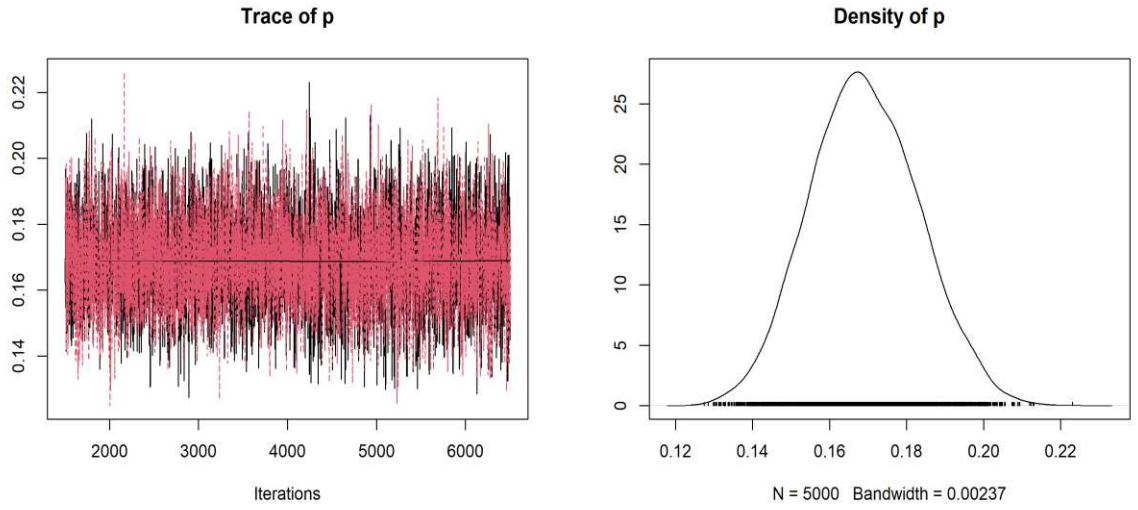


Figure 2. Prevalence and density of newly diagnosed hypertension

The prevalence of newly diagnosed hypertension in men and women is 15.94% and 18.0%, respectively. However, this difference between the sexes is not statistically significant (p = 0.532). Higher proportions, above the overall prevalence, were observed in female patients (18%), married patients (19.36%), those with a secondary (18.26%) or university (28.85%) level of education, patients aged 40 to 59 years (21.29%) or aged 60 years and older (33.92%). In contrast, the lowest prevalence (2.14%) was observed in individuals under 40 years old.

Most patients consumed alcohol (50.98%), were non-smokers (92.02%), had a history of chronic kidney disease (52.10%), were non-diabetic (77.45%), had a family history of newly diagnosed (51.82%), and had a normal body mass index (76.19%). Newly diagnosed was more commonly observed in overweight patients (26.2%), obese patients (37.5%), those with chronic kidney disease (29.6%), and alcohol drinkers (17.6%). **Table 2** shows the distribution of patients according to the Framingham score parameters.

Table 2. Distribution of patients according to parameters of the Canadian Framingham cardiovascular risk score, by newly diagnosed hypertension status (N = 714)

Parameters	**Total patients**		**Newly diagnosed hypertensive**				**P^{HTA+}**
	N=714	%	HTA-	(%)	HTA+	(%)	(%)
SBP (in mm Hg)							
< 120	324	45.38	310	43.4	14	4.32	3.23
120 - 129	111	15.55	97	13.6	14	12.61	9.42
130 - 139	114	15.97	108	15.1	6	5.26	3.93
140 - 149	55	7.70	35	4.9	20	36.36	27.15
150 - 159	47	6.58	20	2.8	27	57.45	42.90
≥160	63	8.82	24	3.4	39	61.90	46.22
Total cholesterol							
<4.1	323	45.24	264	37.0	59	18.27	13.64
4.1 - 5.19	230	32.21	191	26.8	39	16.96	12.66
5.2 - 6.19	157	21.99	135	18.9	22	14.01	10.46
>7.2	4	0.56	4	0.6	0	-	-
HDL cholesterol							
<0.9	128	17.93	96	13.4	32	25.00	18.67
0.9 - 1.19	126	17.65	107	15.0	19	15.08	11.26

1.2 - 1.29	129	18.07	115	16.1	14	10.85	8.10
1.3 - 1.60	176	24.65	137	19.2	39	22.16	16.55
>1.60	155	21.71	139	19.5	16	10.32	7.71
Age (in years)							
≤34	218	30.53	214	30.0	4	1.83	1.37
35-39	62	8.68	60	8.4	2	3.23	2.41
40 - 44	98	13.73	86	12.0	12	12.24	9.14
45-49	54	7.56	52	7.3	2	3.70	2.76
50 - 54	55	7.70	37	5.2	18	32.73	24.44
55 - 59	56	7.84	32	4.5	24	42.86	32.00
60 - 64	49	6.86	39	5.5	10	20.41	15.24
65 - 69	40	5.60	26	3.6	14	35.00	26.13
70 - 74	50	7.00	26	3.6	24	48.00	35.84
≥75	32	4.48	22	3.1	10	31.25	23.33

SBP: systolic blood pressure; HDL: high-density lipoprotein; HTA−: patients without newly diagnosed hypertension; HTA+: patients with newly diagnosed hypertension; pHTA+: proportion of patients with newly diagnosed hypertension.

More than half of the patients with a SBP greater than 150 mm Hg at admission were already hypertensive (Table 2). Only 18.27% had a total cholesterol level lower than 4.1 g/l. Nearly a quarter of the patients had low levels of high-density lipoprotein (HDL) cholesterol. Low proportions (<5%) of hypertensive patients were observed among those under 40 years of age.

3.2. Factors associated with newly diagnosed

Factors associated with newly diagnosed were assessed using univariates and multivariate Bayesian logistic regressions. **Table 3** presents the crude and adjusted odds ratios (cOR and aOR) with their corresponding 95% credible intervals (CrIs) from the univariate and multivariate Bayesian logistic regression models.

Table 3. Univariate and multivariate Bayesian logistic regression models for factors associated with newly diagnosed hypertension

Characteristics	**Univariate**		**Multivariate**	
	cOR	**CrI (l-95%, u-95%)**	**aOR**	**CrI (l-95%, u-95%)**
Age (in years)				
]15-40]	Ref		Ref.	
]40-59]	13.07	[5.85,33.62]	6.49	[2.65,13.26]
≥60	25.03	[10.88,64.23]	25.94	[9.77,54.86]
Sex				
Female	Ref.		Ref.	
Male	0.87	[0.58,1.29]	0.71	[0.43,1.08]
Education level				
Primary or less	Ref.		Ref.	
Secondary	1.92	[1.20,3.11]	4.68	[2.65,7.54]
University	3.46	[1.95,6.18]	10.17	[4.80,18.54]
Marital status				
Unmarried	Ref.		Ref.	
Married	2.39	[1.40,4.22]	2.68	[1.22,4.98]
Residence				
Rural	Ref.		Ref.	

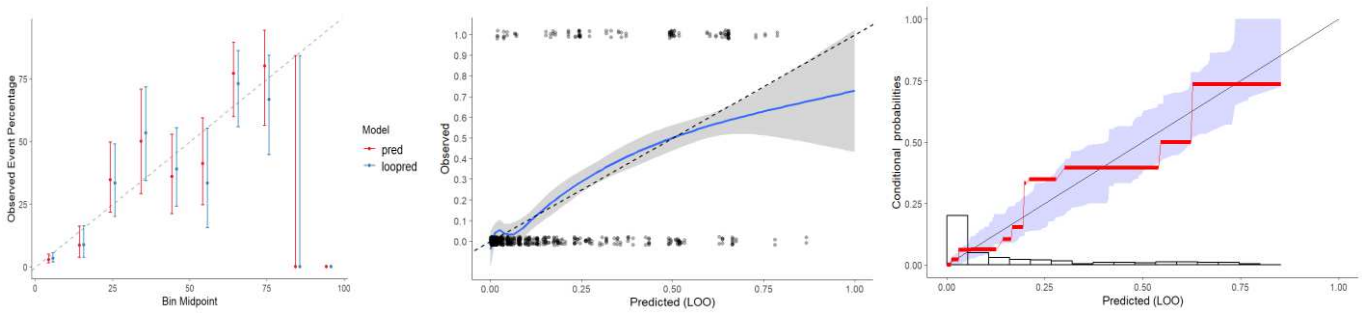
Urban	1.00	[0.67,1.48]	0.94	[0.56,1.42]
Alcohol consumption				
No	Ref.		Ref.	
Yes	1.12	[0.76,1.67]	1.05	[0.66,1.57]
Tabacco consumption				
No	Ref.		Ref.	
Yes	2.25	[1.20,4.11]	3.74	[1.64,6.99]
Diabetes				
No	Ref.		Ref.	
Yes	6.42	[4.22,9.86]	1.64	[0.96,2.59]
Body mass index				
Normal	Ref.		Ref.	
Overweight	2.39	[1.48,3.84]	2.19	[1.22,3.53]
Obesity	4.01	[2.10,7.62]	4.42	[2.02,8.23]
Chronic kidney failure				
No	Ref.		Ref.	
Yes	14.30	[7.62,29.38]	6.58	[3.22, 11.83]
Hypertension in family				
No	Ref.		-	-
Yes	14.59	[7.71,29.80]	-	-

cOR: crude odds ratio; aOR: adjusted odds ratio; CrI: 95% credible interval; Ref.: reference category.

The education level, diabetes, advanced age, obesity, overweight, marital status, chronic kidney failure, and family history of hypertension are significantly associated with newly diagnosed hypertension (**Table 3**).

3-3. Model comparison using leave-one-out cross-validation (LOO).

We evaluated predictive performance using approximate leave-one-out cross-validation (**Figure 3)**. The main model showed good overall fit (posterior classification accuracy=0.86), with an estimated expected log predictive density (elpd_loo) at –226.1 (SE = 15.6) and all Pareto k estimates < 0.7, indicating reliable LOO estimates . In contrast, the intercept-only baseline model performed was substantially worse (elpd_loo = –324.3, SE = 16.1). Direct comparison using loo compare demonstrated a large and statistically decisive improvement in predictive accuracy for the full model:Δ elpd = 98.2 (SE = 13.8) in favor of the main model. This difference corresponds to more than seven standard errors, providing strong evidence that the predictors included in the full model meaningfully improve out-of-sample prediction relative to the baseline. **Figure 3** shows the model calibration.



A. Mean and uncertainty interval **B**. Narrower uncertainties **C.** Estimates of conditional probabilities

Figure 3. Model fitting and calibration based on **(A)** Mean and uncertainty interval, **(B)** Narrower uncertainties and (**C**) estimates of conditional probabilities

3-4. Level of 10-years cardiovascular diseases risk

The level of 10-years cardiovascular diseases risk was assessed in both type of patients (hypertensive and non-hypertensive). **Figure 4** shows the level of Cardiovascular Diseases Morbidity Risk among hypertensive and un hypertensive patients.

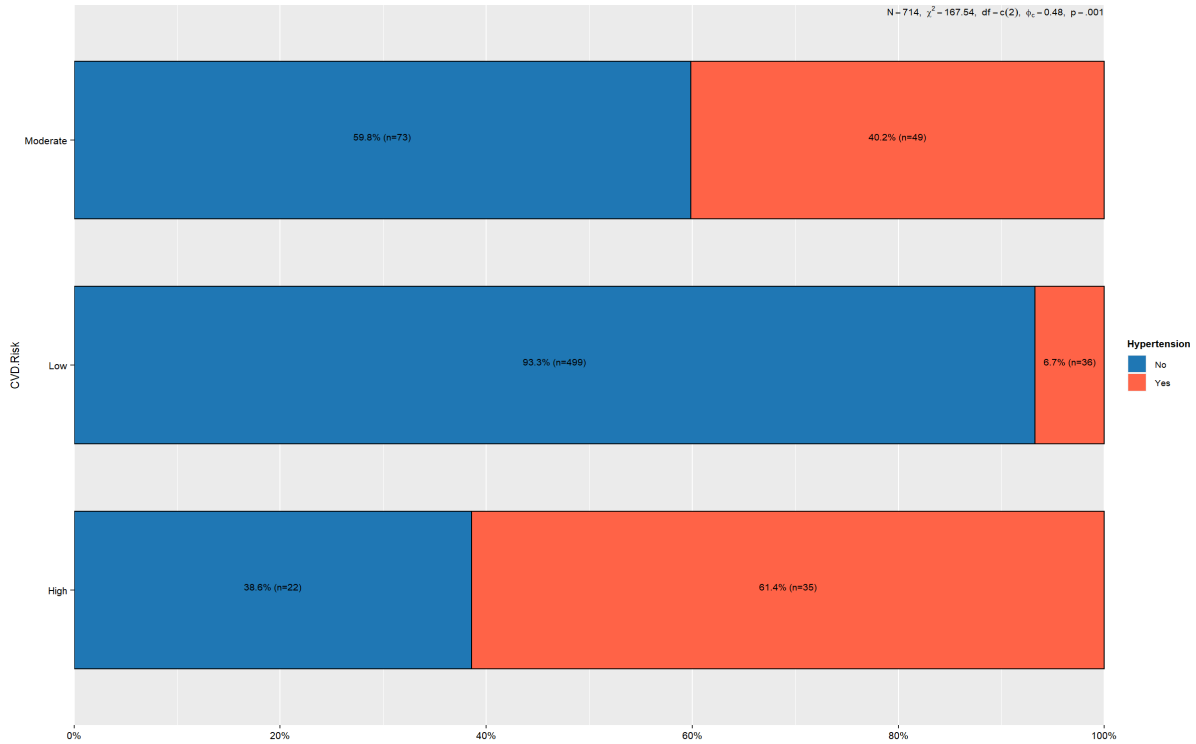


Figure 4. Risk of cardiovascular diseases in hypertensive and non-hypertensive patients

Among the 714 participants, 179 (25.1%) were classified as having moderate or high predicted 10-year cardiovascular risk (**Figure 4**). Among the 120 patients with newly diagnosed hypertension, 35 (29.2%) were classified as high risk. More than two thirds (61.4%) of patients classified having a high 10-year cardiovascular risk are these newly diagnosed with hypertensives. Near half (41.2%) of patients with moderate cardiovascular risk were those with a newly diagnosed hypertension. Most patients with low 10-year cardiovascular risk (93.3%) are not hypertensive. The newly diagnosed hypertension is significantly associated with the 10-year cardiovascular risk ($p<0.05$). **Figure 5** shows the correlation between DBP and 10-year cardiovascular diseases risk among non-hypertensive and hypertensive patients.

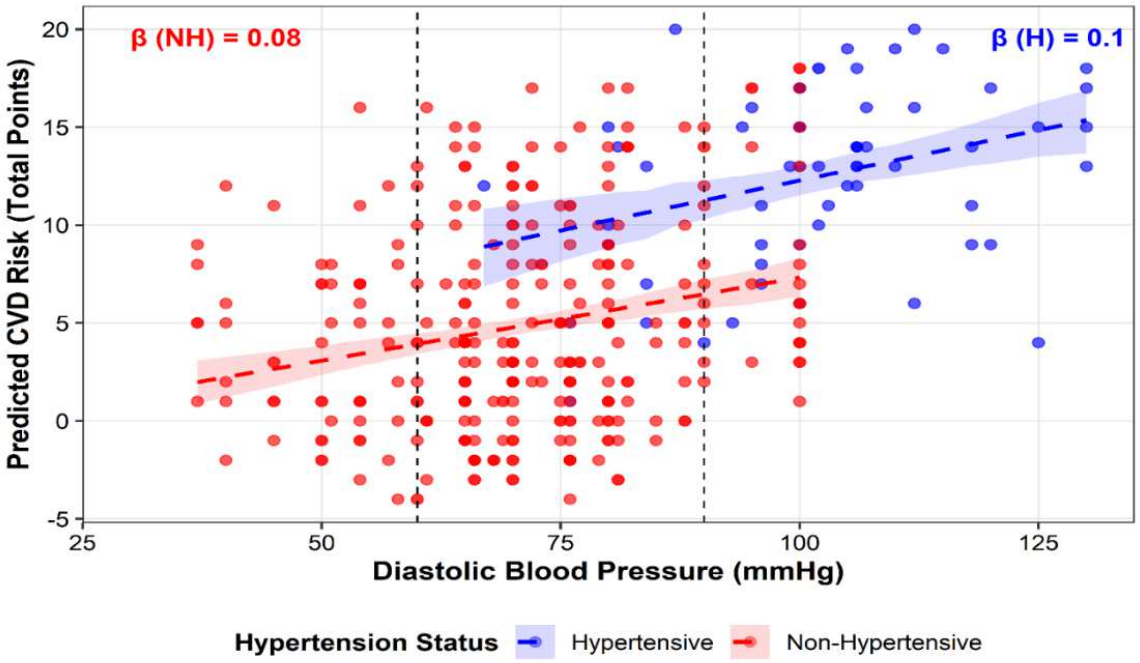


Figure 5. DBP and 10-year CVD risk correlation in non-hypertensive and hypertensive patients.

A positive association between DBP and predicted CVD risk was observed among both hypertensive and non-hypertensive individuals (**Figure 5**). As DBP increased, predicted CVD risk also increased in both groups, with a stronger association among hypertensive participants ($\beta = 0.10$) than among non-hypertensive individuals ($\beta = 0.08$). **Figure 6** shows the distribution of predicted CVD risk levels among hypertensive and non-hypertensive patients, illustrating the differences in risk profiles between the two groups.

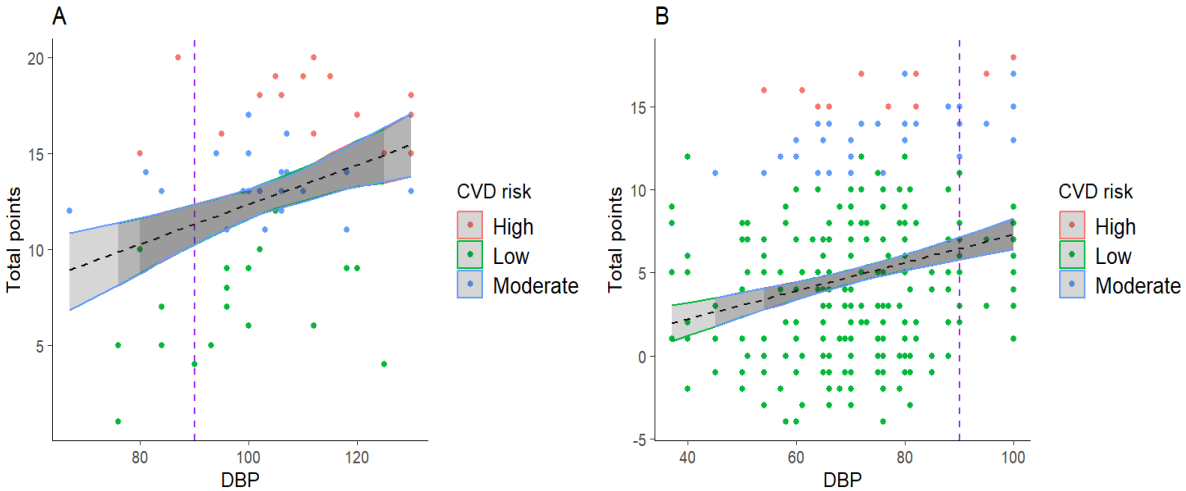


Figure 6. Distribution of CVD risk in hypertensive (**A**) and non-hypertensive (**B**) patients

Higher predicted 10-year CVD risk was more frequently observed among patients with DBP above the threshold of 90 mmHg (**Figure 6A**). In contrast, lower predicted 10-year CVD risk was more commonly observed among patients with DBP below 90 mmHg (**Figure 6B**)

4.Discussion

Arterial hypertension and cardiovascular diseases remain major public-health challenges in Burundi. Using a Bayesian belief update evidence-based method, Bayesian logistic regression, and the Framingham Risk Score (FRS), this study estimated the prevalence of newly diagnosed hypertension, identified associated factors, and assessed 10-year CVD risk.

The prevalence of newly diagnosed hypertension was 16.9% (95% CrI 14.2–19.7), a finding consistent with evidence from Benin (15.2%)[46] , observations from China (23%)[47] , and from Mexico and the United States (24.1%)[48, 49]. In contrast, it is lower than estimates (50%) reported in some recent studies conducted in Africa [50], as well as those observed in Chinese adults over 15 years(28.56%)[51]. The exclusion of known hypertensive individuals before admission and those with incomplete FRS data may partially explain the comparatively lower prevalence. The estimated prevalence is also below the regional average reported for sub-Saharan Africa, possibly due to differences in study populations and sample sizes[52].

Hypertension prevalence in our study was higher among women than men, consistent with findings from Saudi Arabia showing women suffering from hypertension than men over the last three decades [53], and others from Lesotho, and Sudan showing a higher prevalence in women than in men[54, 55]. However, as in Benin and Sweden, the difference between sexes showed a slight female predominance without a statistical significance[46, 56].The higher prevalence among women might reflect post-menopausal hormonal changes, including oestrogen deficiency, arterial wall thickening, and increased arterial stiffness, which have been linked to elevated blood pressure[57, 58].

The highest prevalence of newly diagnosed hypertension was among individuals with diabetes, whereas the lowest prevalence was in adults younger than 40 years. These findings mirror those from studies in Sudan, Côte d'Ivoire, and Ghana, where younger individuals exhibit lower hypertension prevalence [55, 59-62]. They are also consistent with findings from a multicentre study conducted on patients with type 2 diabetes in Ethiopia showing a high prevalence of newly diagnosed hypertension (61%) among diabetics[63]. The strong association between diabetes and hypertension reflects shared risk pathways including physical inactivity and obesity suggesting a bidirectional risk cycle[64].

After adjustment using Bayesian logistic regression tobacco consumption, advanced age, higher education level, overweight and obesity, and history of hypertension were significantly associated with hypertension. Similar associations of hypertension and overweight, smoking, education level, and advanced age have been reported in Kenya and Bangladesh[65, 66]. A recent study in Western Uganda, using the 2017 ACC/AHA guidelines, found also age ≥40 years, overweight, and obesity to be predictors of hypertension [67]. The association between education level and newly diagnosed hypertension was stronger after adjustment. This change may reflect confounding by other covariates particularly age.

The strong association between advanced age and hypertension is in line with biological mechanisms involving progressive arterial resistance and vascular remodeling [68]. Although no sex association was found, the literature suggests that hormonal changes around the age of 45 may increase women's susceptibility to hypertension[69]. The progressive deficiency in oestrogen after menopause could lead to thickening of the arterial wall and increase in the tone of muscle fibres, resulting in greater arterial stiffness and hypertension[57, 58].

Consistent with evidence from studies conducted in Brazil and Ghana showing a high risk of hypertension in married women[70, 71], our study showed an association between marital status and hypertension. These results are also consistent with other studies, where married women had a significantly higher risk of hypertension[70]. However, the association between marital status and hypertension remains inconclusive in the literature from some previous studies[54].

Alcohol consumption also showed no association with hypertension, consistent with findings from Nepal and parts of Europe [72], though contrary to recent reports from India showing alcohol consumption to be a significant risk factor for hypertension[73, 74]. The lack of association may reflect cultural tendencies to underreport lifestyle behaviours on alcohol in Burundi and the absence of alcohol-intake quantification in our dataset. Pathophysiological evidence indicates that alcohol consumption can elevate blood pressure through sympathetic activation and dysregulation of renin–angiotensin–aldosterone system[75].

Kidney disease was associated with hypertension in our analysis. However, the cross-sectional design does not establish whether kidney disease preceded hypertension, and hypertension itself may contribute to the development or progression of kidney disease. Thus, reverse causation and a bidirectional relationship cannot be excluded.

The 10-year CVD risk was present in 25.1% of participants, of whom 30% had high risk. This proportion is lower than estimates from specific high-risk groups in Belgium , such as patients with sleep apnoea, where moderate-to-severe risk reaches nearly 60% [76]. Most individuals with low 10-year risk were normotensive, whereas hypertension was present in over one-third of individuals with moderate risk and in more than half of those with high risk. These findings are consistent with recent studies showing hypertension as main cardiovascular risk factor[77]. The observed high-risk of CVD morbidity in hypertensive patients can be due to the late diagnosis, probably at complication stage.

DBP was positively correlated with cardiovascular risk among both non-hypertensive and hypertensive patients, with a higher proportion of patients at elevated cardiovascular risk observed among those with DBP ≥90 mmHg. These findings are broadly consistent with epidemiological evidence demonstrating an association between higher DBP and cardiovascular risk. Recent observational investigations and clinical trials showed cardiovascular disease to be primarily caused by a right-sided shift in the distribution of DBP**[78].**

Franklin et al. reported that DBP was a particularly strong predictor of coronary heart disease among individuals younger than 50 years, with a 34% increase in coronary heart disease risk per 10-mmHg increase in DBP (HR 1.34, 95% CI 1.18–1.51))[79]. However, the relative importance of DBP as a predictor of cardiovascular outcomes decreases with age, with systolic blood pressure and pulse pressure becoming stronger predictors among older adults[79]. Furthermore, evidence from a meta-analysis of 61 prospective studies demonstrated a graded association between higher blood pressure and vascular mortality, with each 10-mmHg increase in DBP associated with approximately a two-fold increase in vascular mortality risk[80, 81]. Together, these findings support the observed positive association between DBP and cardiovascular risk in our study, while highlighting the importance of considering age and other blood pressure components when assessing cardiovascular risk.

5.Strengths and limitations of this study

This study has several strengths. First, the application of Bayesian methods enabled probabilistic estimation and more comprehensive quantification of uncertainty. Second, the combined assessment of hypertension prevalence, risk-factor modelling, and long-term CVD risk provides an important insights on cardiovascular diseases risk in Burundi. Although the dataset is, to some extent, not nationally representative, the Kamenge Teaching hospital serves patients from across the country, and Bayesian estimation, particularly the Bayesian belief update evidence-based method, improves inference regarding the prevalence distribution.

Despite these strengths, it is important to note some limitations. First, this study is a cross-sectional study using secondary data. Additionally, lifestyle variables, including quantity and type of alcohol or tobacco consumed and physical activity were unavailable while they are well known to be associated with hypertension. Another potential limitation of this study is selection bias arising from the requirement for complete clinical and biological data. The Bayesian approach used in this study does not correct for this potential selection bias. Caution is therefore need when generalizing these findings on newly diagnosed hypertension to the wider Burundian population, given that the study was conducted at a single centre.

These limitations also highlight important priorities for future research in Burundi. Multicentre studies incorporating more comprehensive clinical, lifestyle, and biomarker data are needed to validate and extend these findings. Such studies could also support the development of country-specific CVD risk prediction models that are well calibrated to the Burundian population. Moreover, longitudinal approaches, including methods such as Hidden Markov Models, may provide valuable insights into transitions between different CVD risk states over time[82]. Importantly, future cardiovascular research in Burundi should also investigate the underlying mechanisms linking hypertension and cardiovascular risk, alongside established epidemiological risk factors.

Emerging evidence suggests that inflammatory pathways, including NLRP3 inflammasome activation and gasdermin-D-mediated pyroptosis, may play important roles in cardiovascular pathophysiology[83]. Future research in Burundi could therefore integrate these biological pathways with epidemiological and risk-prediction models to improve understanding of cardiovascular risk and inform more targeted prevention strategies. Further investigation of therapeutic approaches targeting cardiovascular risk and lipid metabolism may also provide opportunities for reducing the burden of cardiovascular disease[84].

6.Policy implications

Hypertension and cardiovascular diseases are major and growing public health concerns in Burundi, requiring urgent policy attention. The burden of newly diagnosed hypertension highlights the need to strengthen routine blood pressure screening and cardiovascular risk assessment, particularly among high-risk groups. Prevention should combine population-level interventions promoting healthy lifestyles with integrated hypertension management within broader NCD programmes. Strengthening health-information systems and nationally representative research will support evidence-based interventions and sustained reductions in CVD burden. However, the benefits of CVD risk prediction tools in sub-Saharan Africa will depend on their effective integration into routine health service[85].

7.Conclusions

This study reveals a burden of newly diagnosed hypertension among hospitalized patients at Kamenge Teaching Hospital, with significant associations with age, education, obesity, tobacco use, and family history of hypertension. A considerable proportion of patients exhibits moderate to high 10-year cardiovascular disease risk according to the Framingham Risk Score, underscoring the substantial but often unrecognised burden of cardiovascular morbidity in the country. The use of Bayesian methods provided robust estimates of prevalence and key risk factors that can inform targeted interventions. These findings highlight the urgent need for systematic blood pressure screening, early diagnosis, and integrated risk-management strategies to mitigate the growing impact of hypertension and cardiovascular diseases in Burundi.

Declarations

Clinical trial number

Not applicable.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research

Authors' contributions

AI conceptualized the study and designed the methodology. AI, ADA, AK collected data. CI conducted the preliminary analysis. CI and AI jointly curated the analysis. RT, POC, ADA, and AK contributed to the intellectual content. ENO, EN and EB supervised the work and reviewed the subsequent versions. All authors approved the final manuscript for publication. AI agreed to handle all correspondence related to the intellectual content of the study and serves as the corresponding author.

Funding

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Data availability

The dataset related to this study is available with the corresponding author and can be available on reasonable request.

Ethics approval and consent to participate

The study was approved by an institutional ethics committee of Kamenge Teaching Hospital (**N/Ref.2023/DGCHUK837/11.5**). No informed consent was needed. All data were fully anonymized before we accessed them. The study was conducted by the guidelines of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests

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8.List of Abbreviations and Acronyms

Abbreviation and Acronyms	Full meaning
%	Percentage
ACC	American College of Cardiology
AHA	American Heart Association
GBD	Global Burden Disease
HDL	High Density Lipoprotein
HTA	Hypertension
HTA-	Non-hypertensive patients
HTA+	Hypertensive patient
CrI	Credible interval
LDL	Low Density Lipoprotein
CVD	Cardiovascular Diseases
WHO	World Health Organization
OR	Odds ratio
aOR	Adjusted Odds ratio
cOR	Crude Odds ratio
P^{HTA+}	Prevalence of Hypertension

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