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ORIGINAL RESEARCH

Evaluating the Hypertension Cascade of Care in Adults in Urban Lao PDR: Evidence From the VITERBI Cohort Study

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Background: Hypertension (HT) is a major risk factor for adult morbidity and mortality in low- and middle-income countries and little is known regarding the distribution of HT risk and treatment access within urban areas.

Patients and methods: We used data from the Vientiane Multi-Generational Birth Cohort in urban Lao PDR to assess the prevalence of loss and retention across five stages of HT care for 40+ year old adults: i) prevalence of hypertension, ii) hypertensives who ever had their BP measured by a health care professional, iii) hypertensives ever diagnosed with HT by a professional, iv) patients currently treated with HT medication, and v) patients with currently controlled BP. We estimated associations between sociodemographic and lifestyle predictors and the proportion of participants who reached each care cascade step using mutually adjusted Poisson regression modeling.

Results: Among the 3196 participants aged 40 to 99 years, the overall prevalence of HT was 16.3%, with higher rates for women, people over 60 years, peripheral district residents, low educated, widowed, and obese. Among people with HT, 90.2% ever had their BP measured by a health care professional, 69.3% ever received a HT diagnosis, 60.9% HT were currently on (drug) treatment, and 39.5% had currently controlled BP. The largest cascade of care losses occurred at the diagnosis and control stages with better outcomes for women. While central districts showed higher rates of diagnosis, control levels were lower than in peripheral districts, but there these differences appeared to be explained by adjusting for sociodemographic and lifestyle factors.

Conclusion: While HT prevalence in Lao PDR is lower than reported for other LMICs, more than 16% over the age of 40 years suffer from HT, and 60% of these cases are currently not controlled. Major policy efforts are needed to support this population and to prevent HT-driven excess mortality.

Keywords: blood pressure, hypertension, hypertension care cascade, Lao People's Democratic Republic

Introduction

Hypertension is a prevalent, long-term, non-communicable disease (NCD) that is a critical risk factor for ischemic heart disease, stroke, chronic kidney disease, and other serious conditions.[1–3] An estimated one-third of all adults globally are suffering from hypertension, disproportionally more in low- and middle-income countries (LIMCs) and are consequently at risk for related sequelae.[4,5] High systolic blood pressure in particular has been identified as a leading risk factor for attributable deaths, accounting for an estimated 10.8 million annual deaths.[6]

While the age-standardized prevalence of hypertension has been decreasing in high-income countries, it has been increasing in LMICs, resulting in a rapid increase in the absolute numbers of hypertensive patients.[4] Regional and temporal heterogeneity in hypertension prevalence are largely based on population age, and presence of genetic and lifestyle-related risk factors.[7,8] The hypertension prevalence variability has been evidenced by recent comprehensive studies.[4,8,9] For the Lao People's Democratic Republic (Lao PDR), two national representative studies showed

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hypertension was present in 20% of adults, with prevalence rates generally increasing with age, body mass index, and decreasing with educational attainment, marital status, and urbanicity.[10,11] A recent study in Lancang-Mekong countries estimated more than a third of adults in this rural area of Lao PDR were hypertensive, indicating regional heterogeneity of hypertension rates.[12]

Risks for cardiovascular morbidity and mortality can be greatly mitigated by hypertension related primary prevention efforts and adequate hypertension care.[13,14] The cascade of care framework can be applied to assess and compare health systems' competence in management of hypertension, which follows patients' progress from being at risk of hypertension to achieving controlled blood pressure.[15] The retention and loss of hypertensive individuals is summarized for critical steps in care management, such as i) accurate diagnosis of hypertension and patient awareness, ii) initiation of appropriate antihypertensive treatment and adherence to prescribed treatment regimens, and iii) achievement of target blood pressure control. The latest global estimates suggest that slightly more than half of hypertensive adults have been diagnosed with HT, two-fifths receive treatment, and a fifth have their hypertension controlled.[4,5] These rates were higher for women and varied greatly by geography, generally being less favorable in LMICs. Specific reports on the hypertension care cascade in Lao PDR are scarce. A national representative study in 2013 found HT diagnose awareness, treatment, and control at 29.3%, 18.2%, and 16.7%, respectively.[10] A similar study in 2020 found higher rates for all cascade steps at 54.5%, 43.8% and 23%, with better cascade performance for women and the urban population.[11]

Capitalizing on the first multigenerational birth cohort in Lao PDR, the aim of our study was to quantify gaps in the hypertension care cascade in urban and semi-urban areas of Vientiane capital and identify predictive factors for individual cascade steps.

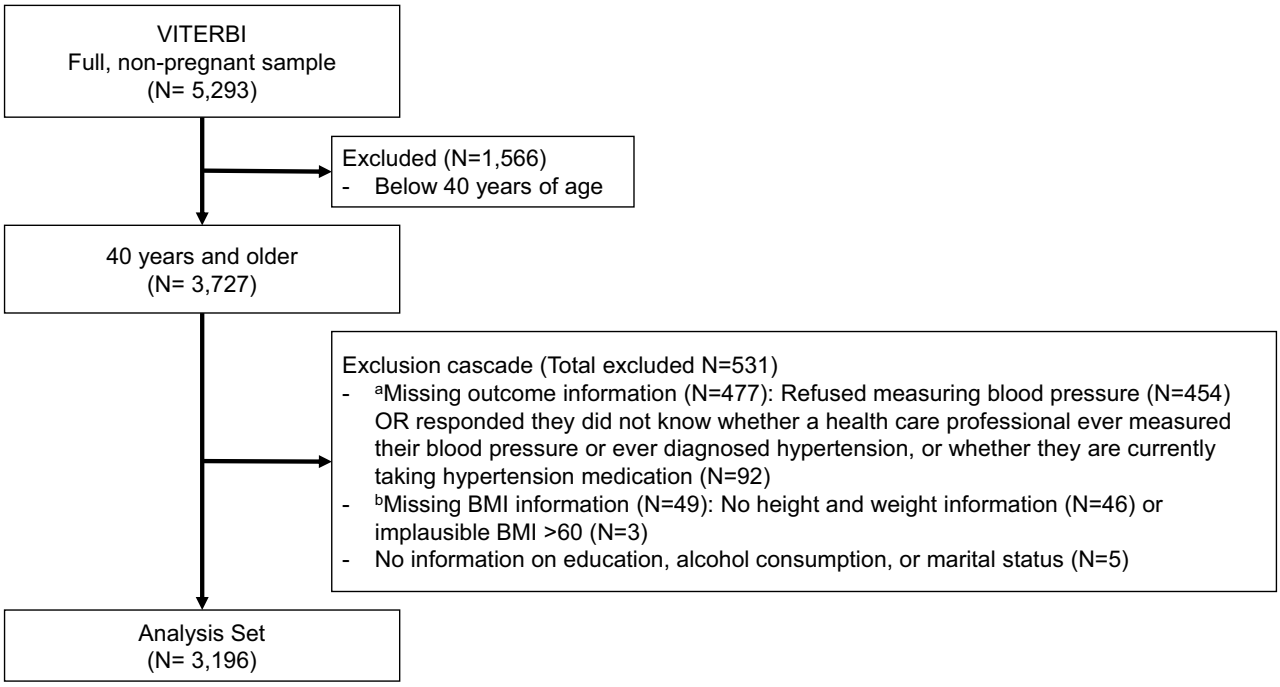
Methods

Study Design

This is a cross-sectional study using baseline data collected as part of the VIentiane mulTi gEneRational BIrth cohort (VITERBI).[16] VITERBI is a multi-generational birth cohort in the Vientiane Capital region designed for comprehensive coverage ensuring representativeness of the local population. Two urban districts of high socioeconomic status (Chanthabuly and Sikhottabong) and two semi-urban, less developed districts (Sangthong and Parkngum) were purposely selected for the study to assess urban disparities. According to the most recent 2015 housing census, the total populations of Chanthabuly, Sikhottabong, Sangthong, and Parkngum were 69,200, 121,000, 29,500, and 49,200, respectively, with Sikhottabong and Sangthong projected to experience larger population increases.[17,18] Sangthong and Parkngum had a poverty gap index about twice as high as the other included districts.[19] After an initial pilot phase conducted in 2021, VITERBI aimed to enroll all newborns between 1 July 2022 and 30 June 2023 including assessments of their mother (index women) and father, grandparents and great-great parents. For the present analysis, we included data from study enrollment up to June 2024 and participants providing signed informed consent. We excluded all index women, who were either pregnant or had recently completed a pregnancy at the time of the assessment, and adults below the age of 40 years (Figure 1) to ensure a sex balanced sample and exclude potential hypertensive disorders in pregnancy.[20] Out of the 5293 adult non-pregnant participants in the VITERBI study, 3727 (70.4%) were 40 years and older (Figure 1). Among the latter, 3250 (87.2%) agreed to have their blood pressure measured, and knew and reported (ie none refused to answer) their hypertension history and current hypertension medication. Finally, 3196 (85.8%) had complete information on all variables and were thus included in the analysis set.

Data Collection Procedures

All data was collected by trained study staff at the participant's home or in a community setting and the full battery of assessments took around 90 minutes per participant. Information on socio-demographic, socio-economic and cardiovascular risk factors was collected using a pretested questionnaire, with responses recorded electronically via the Open Data Kit (ODK) application on Android tablets. Blood pressure was measured using automated OMRON- HEM-7121 blood pressure monitors, with the participant's arm resting and supported at the level of the heart. Blood pressure measures were taken at the beginning, the middle and the end of the questionnaire, allowing 10 min resting position before each



[a] Significant difference between included and excluded regarding level of education attained, marital status, and income
[b] Significant difference between included and excluded regarding sex and income

Figure 1 Flow diagram of the sample-selection process.

measurement. Height and weight were measured using a portable stadiometer to the nearest 0.1 cm and portable scales to the nearest 0.01 kg respectively (Seca Instruments, Hamburg, Germany).

Outcome Variables

We defined the outcomes following the hypertension control cascade framework definitions put forward by Wozniak et al.[15] We used the mean of the last two BP measurements to derive systolic and diastolic blood pressure levels, as these are generally perceived as reflecting blood pressure more accurately than the first/initial measurement.[21] Hypertension was defined as systolic blood pressure of at least 140 mm Hg or diastolic blood pressure of at least 90 mm Hg or reported current (ie within the last 2 weeks) use of medication for hypertension. For the cascade of hypertension care, we defined four levels i) "measured" if hypertensive respondents reported their blood pressure was ever measured by a doctor or other health care professional, ii) "diagnosed" if they were ever told by a doctor or other health care professional that they had high blood pressure (ie aware of their hypertension), iii) "treated" if they were currently taking any antihypertensive medication, iv) blood pressure "controlled" if they were treated and had a systolic blood pressure of less than 140 mm Hg and a diastolic blood pressure of less than 90 mm Hg.

Explanatory Variables

We included the following, previously identified key predictors of hypertension or hypertension care that were available in our study.[8–10,22,23] We grouped participant age in ten-year intervals from 40 to 80 years. Due to smaller numbers, we grouped all individuals 80 years and older together. We further dichotomized the sample by retirement age, commonly at age 60 years in Lao PDR.[24] We grouped the four study districts of residence by the proximity to the city center into peripheral (Sangthong and Parkngum) and central (Chanthabily and Sikhottabong) residence. Highest education level attained was grouped into no schooling, primary (any level of primary 1–6 completed), secondary (any level of secondary 1–6 completed), or higher (any number of university years or higher completed). Current marital status was grouped as married (married or cohabitating), widowed, or alone (divorced, separated, or never married). Information on whether

a participant earned an income (yes vs no) and quantiles of the income level (in Laotian Kip) were combined in a composite income variable (no income, income-level quantiles 1–5). Participants reporting no income were further broken down into employed, unemployed, homemaker, retired, or other. We derived body mass index (BMI) categories from the participants' weight and height measurements using the World Health Organization's BMI classification criteria: underweight (below 18.5 kg/m²), normal weight (18.5–24.9), overweight (25–29.9), and obese (30 and more).[25,26] Three participants with BMI over 60 were excluded due to implausible height-to-weight ratios. Alcohol intake was described as the frequency of current alcohol consumption (never, at least monthly, 2–4 times a month, or, twice or more a week) and tobacco use was defined as current, previous, or never smoking.

Statistical Analysis

Complete case analysis was used for all analyses outlined below, ie excluding 531 participants with missing information on hypertension outcome or explanatory variables (Figure 1). Exclusion due to missing outcome information was related to level of education attained (higher for no school or highest school attainment), marital status (lower for married) and income (higher for no income and highest income quintiles) but not to age, sex or residence. Additional exclusion due to missing independent variable information was related to sex (men vs women: 2.3 vs 0.9%) and income (higher for no income and highest income quintiles) but not to age, residence, education attained, or marital status.

We summarized socio-demographic and lifestyle variables as total counts and percentages overall and stratified by sex. Group differences were tested using chi-squared or analysis of variance tests, as appropriate. Kernel-weighted local polynomial regression analysis explored age gradients of hypertension and BMI, and the BMI gradient of hypertension.

We described the total and stratified (by socio-demographic and lifestyle variables) prevalence of i) measured among those with hypertension, ii) diagnosed among those with hypertension, iii) treated among those who were diagnosed, and iv) controlled blood pressure among the treated. We further described cumulative losses for the overall care cascade, keeping the denominator constant (ie relative to all hypertensives), as total and by sex, residence, and retirement age strata.

For each cascade step, we regressed the proportion of participants with hypertension who reached the given step on sex, 10-year age group, residence, educational level attained, marital status, income, body mass index, alcohol consumption, and smoking status. Poisson regression modeling containing all independent variables was used to estimate risk ratios, which we reported together with the corresponding standard errors.

None of the analyses were pre-specified and are exploratory in nature. All analyses were conducted in STATA 18 SE[27] and p-values of <0.05 were considered statistically significant.

Ethics Statement

Ethical approval for the study was obtained from the Ethics Commission of Northwestern and Central Switzerland (EKNZ, 2020–00037) and the National Ethic Committee of Health Research, Ministry of Health, Lao PDR (035/NECHR). The study complies with the declaration of Helsinki and written informed consent was obtained for all participants. Index women gave consent for themselves and their newborns. For minors (age < 18 years), both the minor and a parent or legal guardian provided consent. For participants who were illiterate, there was an additional witness who was not part of the study team.

Results

Population Characteristics

In total, 3196 respondents were included in this study (Figure 1). The average age of the participants was 57.4 years, ranging from 40 to 99 years, with no significant difference in means by sex (Table 1). The majority of participants resided in the central areas (63.7%), similarly so for sexes. Women were more than twice as likely to report no schooling, while reaching the highest education level was over three times more common among men. Our "married" group indicated to be married (99.8%) or cohabitating (0.2%), and the "alone" group consisted of divorced (69.2%), separated (26.2%), or never married (4.6%) participants. Women were much more likely to be widowed (13.6% vs 3.4%) and more men were in a marital relationship (95.2% vs 83.9%). Slightly more than a fifth of all participants reported no income, whereas this was substantially higher for women than for men. Participants indicating they had no

Table 1 Socio-Demographic Characteristics of Participants with Hypertension

	Total		Male		Female	
	No.	**%**	**No.**	**%**	**No.**	**%**
Total (Row %)	3196	(100.0)	1461	(45.7)	1735	(54.3)
Age [years]						
Mean (SE)	57.4	0.19	57.1	0.27	57.6	0.27
40–49	784	(24.5)	351	(24.0)	433	(25.0)
50–59	1281	(40.1)	583	(39.9)	698	(40.2)
60–69	676	(21.2)	346	(23.7)	330	(19.0)
70–79	328	(10.3)	141	(9.7)	187	(10.8)
80+	127	(4.0)	40	(2.7)	87	(5.0)
Residence						
Central	2035	(63.7)	932	(63.8)	1103	(63.6)
Peripheral	1161	(36.3)	529	(36.2)	632	(36.4)
Level of education attained						
Primary	2172	(68.0)	879	(60.2)	1293	(74.5)
No school	205	(6.4)	58	(4.0)	147	(8.5)
Secondary	592	(18.5)	351	(24.0)	241	(13.9)
Higher	227	(7.1)	173	(11.8)	54	(3.1)
Marital status						
Married	2846	(89.0)	1391	(95.2)	1455	(83.9)
Widowed	285	(8.9)	49	(3.4)	236	(13.6)
Alone	65	(2.0)	21	(1.4)	44	(2.5)
Income						
None	937	(29.3)	212	(14.5)	725	(41.8)
Quintile 1	634	(19.8)	327	(22.4)	307	(17.7)
Quintile 2	519	(16.2)	262	(17.9)	257	(14.8)
Quintile 3	567	(17.7)	319	(21.8)	248	(14.3)
Quintile 4	264	(8.3)	169	(11.6)	95	(5.5)
Quintile 5	275	(8.6)	172	(11.8)	103	(5.9)
BMI						
Normal Weight	2422	(75.8)	1127	(77.1)	1295	(74.6)
Underweight	57	(1.8)	20	(1.4)	37	(2.1)
Overweight	615	(19.2)	284	(19.4)	331	(19.1)
Obese	102	(3.2)	30	(2.1)	72	(4.1)
Alcohol Consumption: Current						
Never	1571	(49.2)	340	(23.3)	1231	(71.0)
Monthly	857	(26.8)	571	(39.1)	286	(16.5)
2–4 a Month	710	(22.2)	501	(34.3)	209	(12.0)
>2 a Week	58	(1.8)	49	(3.4)	9	(0.5)
Smoking Status						
Current smoker	624	(19.5)	614	(42.0)	10	(0.6)
Previous smoker	134	(4.2)	127	(8.7)	7	(0.4)
Never smoked	2438	(76.3)	720	(49.3)	1718	(99.0)

income were mostly homemakers (60.0%) or unemployed (28.3%), and only 6 (0.6%) indicated they were retired. Obesity was present in 102 (3.2%) participants, predominantly in women (4.1% vs 2.1%). We found a marked decline in BMI for ages over 60 years (Figure s1). Alcohol consumption was much more common in men, and over two-thirds

of women reported to not consume alcohol at all (Table 1). Similarly, virtually no woman reported to ever having been a smoker, while men frequently were current smokers (42.0%).

Prevalence and Predictors of Hypertension

The overall prevalence of hypertension was 16.3%, significantly higher for women than for men in the sample (17.6% vs 14.9%, $p < 0.038$) (Table 2). Hypertension strongly increased with age, from 7.7% among adults between 40 and 50 years and 22.5% to 25.9% among individuals over 60 years. A positive linear hypertension-age trend was evident (Figure s2). In single variable correlations, we found statistically significant increases in HT prevalence for all socio-demographic and lifestyle factors (Table 2), ie peripheral residence, lowest educational level attained, widowed marital status, no income, non-normal body mass index (specifically obesity), no or frequent alcohol consumption, and previous smoking. Non-parametric exploratory analysis further showed higher hypertension rates for non-normal BMIs, and more clearly so for BMIs over 25 (Figure s3).

Table 2 Prevalence, Diagnosis, Treatment, and Control of Hypertension by Socio-Demographic Factors

	Total	Hypertension		Measured		Diagnosed		Treated[a]		Controlled[b]	
	No.	No.	%	No.	%	No.	%	No.	%	No.	%
Total	3196	522	(16.3)	471	(90.2)	362	(69.3)	318	(87.8)	206	(64.8)
Sex											
Male	1461	**217**	**(14.9)**	**188**	**(86.6)**	**126**	**(58.1)**	109	(86.5)	66	(60.6)
Female	1735	**305**	**(17.6)**	**283**	**(92.8)**	**236**	**(77.4)**	209	(88.6)	140	(67.0)
Age [years]											
40–49	784	**60**	**(7.7)**	55	(91.7)	**34**	**(56.7)**	27	(79.4)	19	(70.4)
50–59	1281	**195**	**(15.2)**	173	(88.7)	**127**	**(65.1)**	115	(90.6)	80	(69.6)
60–69	676	**152**	**(22.5)**	139	(91.4)	**115**	**(75.7)**	100	(87.0)	63	(63.0)
70–79	328	**85**	**(25.9)**	79	(92.9)	**62**	**(72.9)**	55	(88.7)	35	(63.6)
80+	127	**30**	**(23.6)**	25	(83.3)	**24**	**(80.0)**	21	(87.5)	9	(42.9)
Residence											
Central	2035	**298**	**(14.6)**	272	(91.3)	**196**	**(65.8)**	174	(88.8)	**129**	**(74.1)**
Peripheral	1161	**224**	**(19.3)**	199	(88.8)	**166**	**(74.1)**	144	(86.7)	**77**	**(53.5)**
Level of education attained											
Primary	2172	**334**	**(15.4)**	304	(91.0)	233	(69.8)	211	(90.6)	**150**	**(71.1)**
No school	205	**57**	**(27.8)**	50	(87.7)	40	(70.2)	31	(77.5)	**12**	**(38.7)**
Secondary	592	**93**	**(15.7)**	80	(86.0)	58	(62.4)	48	(82.8)	**27**	**(56.2)**
Higher	227	**38**	**(16.7)**	37	(97.4)	31	(81.6)	28	(90.3)	**17**	**(60.7)**
Marital status											
Married	2846	**429**	**(15.1)**	389	(90.7)	294	(68.5)	258	(87.8)	171	(66.3)
Widowed	285	**83**	**(29.1)**	73	(88.0)	62	(74.7)	54	(87.1)	33	(61.1)
Alone	65	**10**	**(15.4)**	9	(90.0)	6	(60.0)	6	(100.0)	2	(33.3)
Income											
None	937	**226**	**(24.1)**	207	(91.6)	167	(73.9)	**147**	**(88.0)**	**83**	**(56.5)**
Quintile 1	545	**45**	**(8.3)**	42	(93.3)	35	(77.8)	**35**	**(100.0)**	**35**	**(100.0)**
Quintile 2	566	**65**	**(11.5)**	57	(87.7)	40	(61.5)	**36**	**(90.0)**	**26**	**(72.2)**
Quintile 3	260	**36**	**(13.8)**	33	(91.7)	23	(63.9)	**22**	**(95.7)**	**15**	**(68.2)**
Quintile 4	445	**80**	**(18.0)**	73	(91.2)	52	(65.0)	**39**	**(75.0)**	**25**	**(64.1)**
Quintile 5	443	**70**	**(15.8)**	59	(84.3)	45	(64.3)	**39**	**(86.7)**	**22**	**(56.4)**
BMI											
Normal Weight	2422	**329**	**(13.6)**	296	(90.0)	229	(69.6)	205	(89.5)	**144**	**(70.2)**
Underweight	57	**14**	**(24.6)**	11	(78.6)	9	(64.3)	6	(66.7)	**5**	**(83.3)**
Overweight	615	**144**	**(23.4)**	133	(92.4)	98	(68.1)	82	(83.7)	**45**	**(54.9)**
Obese	102	**35**	**(34.3)**	31	(88.6)	26	(74.3)	25	(96.2)	**12**	**(48.0)**

(*Continued*)

Table 2 (Continued).

	Total	Hypertension		Measured		Diagnosed		Treated[a]		Controlled[b]	
	No.	No.	%	No.	%	No.	%	No.	%	No.	%
Current Alcohol Consumption											
Never	1571	**341**	**(21.7)**	**316**	**(92.7)**	**251**	**(73.6)**	**223**	**(88.8)**	142	(63.7)
Monthly	857	**110**	**(12.8)**	**99**	**(90.0)**	**74**	**(67.3)**	**64**	**(86.5)**	38	(59.4)
2–4 a Month	710	**59**	**(8.3)**	**49**	**(83.1)**	**31**	**(52.5)**	**28**	**(90.3)**	24	(85.7)
>2 a Week	58	**12**	**(20.7)**	**7**	**(58.3)**	**6**	**(50.0)**	**3**	**(50.0)**	2	(66.7)
Smoking Status											
Current smoker	624	**77**	**(12.3)**	65	(84.4)	**39**	**(50.6)**	**33**	**(84.6)**	23	(69.7)
Previous smoker	134	**35**	**(26.1)**	34	(97.1)	**23**	**(65.7)**	**15**	**(65.2)**	8	(53.3)
Never smoked	2438	**410**	**(16.8)**	372	(90.7)	**300**	**(73.2)**	**270**	**(90.0)**	175	(64.8)

Notes: Bold face numbers and corresponding percentages were statistically significantly (p-value <0.05) related with outcome using a chi-squared test. [a] Diagnosed patients receiving treatment, N=8 responded they took treatment but were never diagnosed. [b] Among those receiving treatment and having been diagnosed.

In multivariable analysis adjusting for all socio-demographic and lifestyle variables, the following were statistically significantly associated with hypertension (Table 3). The risk for hypertension increased for older age groups and widowed participants compared to married ones. Likewise, risks were higher for lower income levels compared to no income and for overweight and more pronouncedly obesity compared to normal weight. Conversely, moderate alcohol consumption was related to lower hypertension risk compared to no alcohol consumption. Sex, residence, educational attainment, and smoking status were not associated with hypertension risk in the adjusted model.

Table 3 Mutually Adjusted Risk Ratios (SE) of Prevalence, Diagnosis, Treatment, and Control of Hypertension and Socio-Demographic and Lifestyle Factors

	Hypertension	Measured	Diagnosed	Treated	Controlled Among Treated	Controlled Among Hypertensive
Sex						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	0.88 (0.110)	1.09 (0.148)	1.35 (0.211)	0.92 (0.156)	1.32 (0.297)	1.64* (0.345)
Age [years]						
40–49	1.00	1.00	1.00	1.00	1.00	1.00
50–59	1.98*** (0.298)	0.95 (0.151)	1.11 (0.219)	1.15 (0.257)	0.94 (0.254)	1.21 (0.319)
60–69	2.49*** (0.402)	0.98 (0.168)	1.30 (0.271)	1.12 (0.259)	1.01 (0.282)	1.49 (0.415)
70–79	2.60*** (0.502)	0.99 (0.200)	1.29 (0.312)	1.16 (0.305)	0.95 (0.303)	1.45 (0.460)
80+	2.14** (0.537)	0.89 (0.241)	1.41 (0.422)	1.18 (0.383)	0.79 (0.355)	1.25 (0.551)
Residence						
Central	1.00	1.00	1.00	1.00	1.00	1.00
Peripheral	1.08 (0.106)	0.97 (0.103)	1.09 (0.129)	0.96 (0.125)	0.76 (0.126)	0.80 (0.129)
Education						
Primary	1.00	1.00	1.00	1.00	1.00	1.00
No school	1.26 (0.195)	0.96 (0.159)	0.92 (0.169)	0.83 (0.173)	0.57 (0.182)	0.40** (0.127)
Secondary	1.13 (0.143)	0.99 (0.137)	0.96 (0.155)	0.94 (0.167)	0.89 (0.204)	0.83 (0.188)
Higher	1.09 (0.200)	1.14 (0.223)	1.23 (0.269)	1.09 (0.255)	1.00 (0.295)	1.34 (0.393)
Marital status						
Married	1.00	1.00	1.00	1.00	1.00	1.00
Widowed	1.36* (0.180)	0.96 (0.136)	0.94 (0.146)	1.00 (0.166)	1.03 (0.217)	0.97 (0.205)
Alone	1.20 (0.387)	1.00 (0.344)	0.83 (0.347)	1.17 (0.502)	0.55 (0.401)	0.49 (0.353)

(*Continued*)

https://doi.org/10.2147/VHRM.S506857

Table 3 (Continued).

	Hypertension	Measured	Diagnosed	Treated	Controlled Among Treated	Controlled Among Hypertensive
Income						
None	1.00	1.00	1.00	1.00	1.00	1.00
Quintile 1	0.61** (0.111)	1.06 (0.196)	1.21 (0.246)	1.10 (0.243)	1.51 (0.365)	1.96** (0.449)
Quintile 2	0.71* (0.109)	0.98 (0.160)	0.99 (0.188)	1.00 (0.202)	1.17 (0.287)	1.19 (0.289)
Quintile 3	0.85 (0.160)	1.02 (0.202)	1.01 (0.236)	1.06 (0.260)	1.04 (0.312)	1.11 (0.327)
Quintile 4	1.09 (0.162)	1.00 (0.160)	1.03 (0.192)	0.83 (0.174)	1.11 (0.291)	0.94 (0.249)
Quintile 5	0.93 (0.147)	0.92 (0.154)	0.97 (0.185)	1.01 (0.208)	1.03 (0.278)	1.00 (0.266)
BMI						
Normal weight	1.00	1.00	1.00	1.00	1.00	1.00
Underweight	1.26 (0.351)	0.84 (0.264)	0.86 (0.301)	0.73 (0.308)	1.29 (0.619)	0.88 (0.414)
Overweight	1.73*** (0.179)	1.02 (0.111)	0.96 (0.122)	0.96 (0.136)	0.84 (0.155)	0.73 (0.131)
Obese	2.72*** (0.495)	0.99 (0.193)	1.05 (0.225)	1.15 (0.255)	0.74 (0.235)	0.85 (0.265)
Current Alcohol Consumption						
Never	1.00	1.00	1.00	1.00	1.00	1.00
Monthly	0.64*** (0.082)	0.98 (0.131)	1.04 (0.162)	0.98 (0.167)	1.03 (0.225)	1.00 (0.207)
2–4 a Month	0.56*** (0.092)	0.89 (0.160)	0.84 (0.184)	0.95 (0.232)	1.20 (0.334)	1.03 (0.273)
≥2 a Week	1.11 (0.340)	0.64 (0.257)	0.82 (0.355)	0.56 (0.341)	1.05 (0.819)	0.48 (0.356)
Smoking Status						
Current smoker	1.00	1.00	1.00	1.00	1.00	1.00
Previous smoker	1.34 (0.282)	1.14 (0.255)	1.20 (0.330)	0.73 (0.237)	0.90 (0.388)	0.71 (0.301)
Never smoked	1.05 (0.161)	0.96 (0.161)	1.09 (0.226)	1.03 (0.233)	0.90 (0.261)	0.95 (0.262)
N	3196	522	522	362	318	522

Notes: Risk Ratios and Standard Errors in parenthesis. * p-value < 0.05, ** p-value < 0.01, *** p < 0.001.

Prevalence and Predictors of Hypertension Diagnosis and Treatment

A vast majority (90.7%) of hypertensive participants reported that their blood pressure had ever been measured by a health professional (Table 2). This appeared consistently high across most socio-demographic and lifestyle factors but was significantly lower for men and for those with more frequent alcohol consumption. The fully adjusted model showed no significant associations with the hypertension "ever measured" outcome (Table 3).

Among those with hypertension, 69.3% had previously been diagnosed with hypertension by a health care professional with significantly higher awareness among women compared to men (77.4 vs 58.1%, $p<0.001$) (Table 2). Participants were more likely to be in the diagnosed group with higher age, living in the periphery, current alcohol abstinence or infrequent consumption, and not currently smoking. Education attained, marital status, income, and BMI were not associated with having been diagnosed. In the full model containing all explanatory variables, none of these factors increased the likelihood of having been diagnosed (Table 3).

A vast majority (87.8%) of those aware of their hypertension (ie previously diagnosed) were HT treated, ie reporting they were taking blood pressure medication (Table 2). Being in the treated group was associated with less frequent alcohol consumption, no or lower income, and previous smoking. None of the explanatory factors were related to treatment status in the fully adjusted model (Table 3).

Blood Pressure Control and the Hypertension Care Cascade

Among patients on HT medication, 64.8% were blood pressure controlled (Table 2). Single variable correlations revealed significant associations between being BP controlled and central residence, at least primary school level educational attainment, lower income groups, and not being overweight or obese. In the full, mutually adjusted model, none of the explanatory variables was associated with blood pressure control among the HT treated, albeit the lowest level of educational attainment (none vs primary school) was borderline significantly associated with less control (RR, SE, *p*-value: 0.57, 0.182, 0.076). Looking at control rates among all hypertensives, being a woman (RR, SE, *p*-value: 1.64,

0.345, 0.019) and lowest income (vs no income) were significantly positively associated with being BP controlled. Conversely, the lowest level of educational attainment was related to lower control.

The overall hypertension care cascade details the prevalence of each step relative to all hypertensives with 90.2% for HT measured, 69.3% for HT diagnosed, 60.9% for HT treated, and 39.5% for controlled participants (Figure 2). Of the total 60.5% who were lost in the care cascade, 30.7% were lost by the diagnosis stage, 8.4% at the treatment stage and 21.4% at the control stage, respectively. We found clear sex differences with 15.5% more men being lost in the care cascade, which was significant in the fully adjusted the model (Figure 3 and Table 3). These differences were present at each care cascade step, most notably with 19.3% more of hypertensive women being diagnosed and 15.5% more being controlled compared to men. The biggest difference in loss between sexes occurred from being measured to being diagnosed, where 13.1% more men were

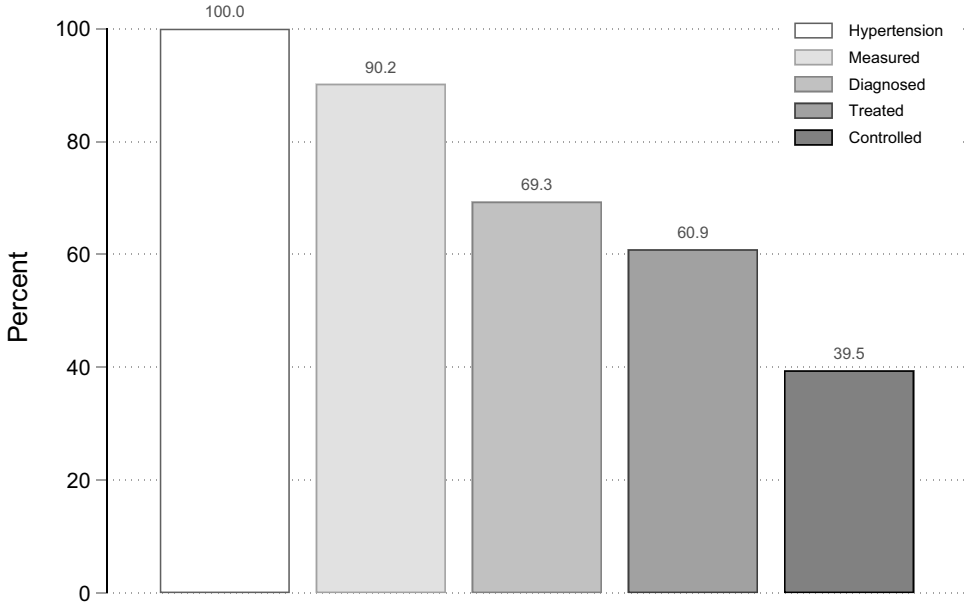


Figure 2 Hypertension cascade of care for all hypertensives.

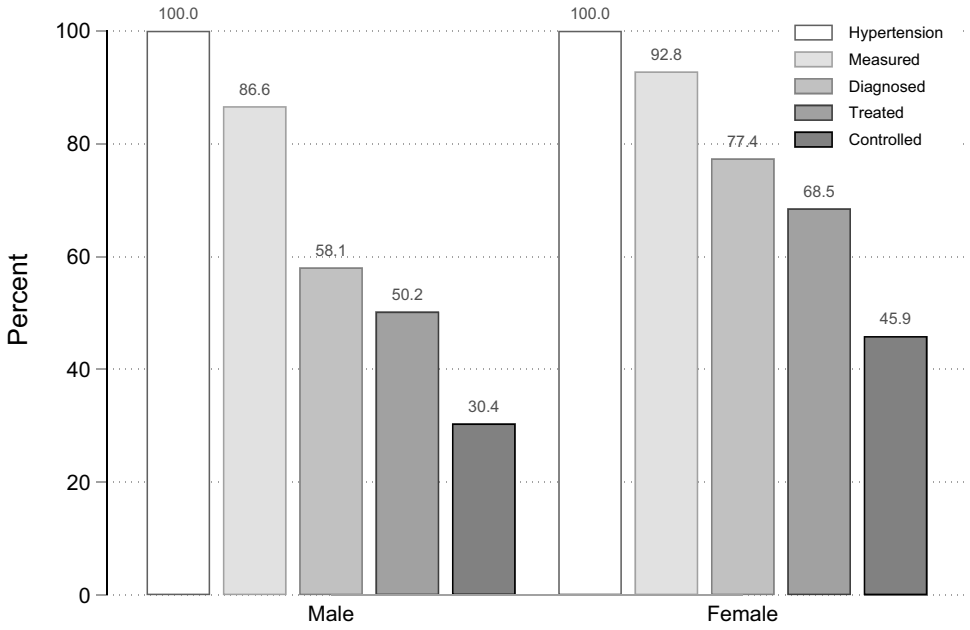


Figure 3 Hypertension cascade of care by sex.

https://doi.org/10.2147/VHRM.S506857

lost, resulting in losing over two-fifths of men (41.9%) vs slightly more than one-fifth of women (22.6%) by the diagnosis stage. Hypertension "ever measured" rates between central and peripheral residents were similar, but there appeared to be a marked loss at the diagnosed stage in central areas (10.8% difference), however not significant in the adjusted model (Figure 4 and Table 3). Conversely, there was a substantially bigger loss for peripheral residents at the control stage (14.8% difference), while there were smaller differences at the treated stage. Finally, central residents appeared to be better controlled (by 8.9%) in the cascade, albeit not significantly so in full models (Table 3). While participants at retirement age showed higher rates of being diagnosed (12.2% difference) and treated (10.2%), they were lost at much higher rate at the control stage (25.8% vs 16.9% loss) (Figure 5). Consequently, we found similar levels of being controlled for both age groups.

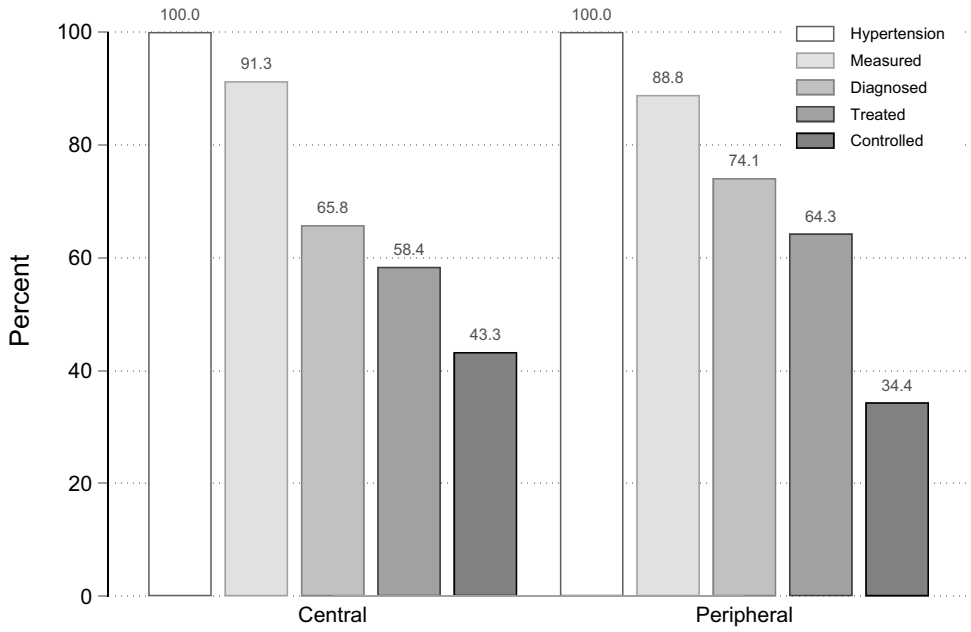


Figure 4 Hypertension cascade of care by residence.

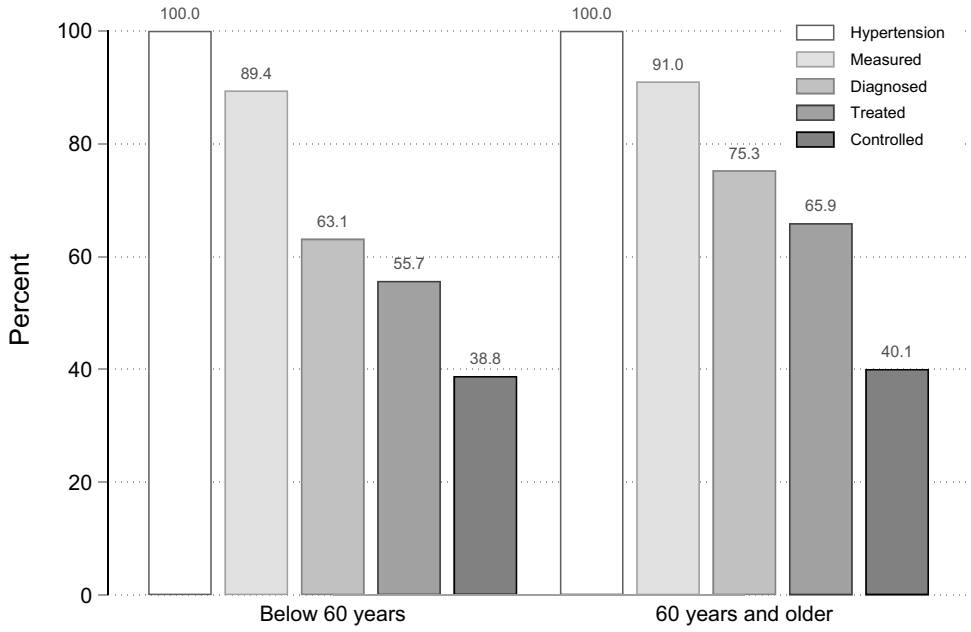


Figure 5 Hypertension cascade of care by retirement age.

Discussion

This study, using a large urban and semi-urban cohort in Lao PDR, presents three main findings: first, as generally seen in the global literature, the prevalence of hypertension in this setting increased strongly with age and body mass index. We also found substantially higher rates among widowed individuals. While we found higher rates of HT in peripheral areas, residential prevalence differences were explained when adjusting for sociodemographic and lifestyle factors, most notably by age and BMI. Second, access to HT care appeared to work well in this setting compared to LMICs in general: we found that over two-thirds were diagnosed with hypertension and close to 90% among those were treated. However, despite these relatively high access numbers, only two-fifths of hypertensives had a controlled blood pressure. The largest losses at the diagnosed and control step of the cascade suggest critical points to improve in the cascade of care, allowing better outcomes in managing hypertension sequelae. Third, we demonstrated better cascade performance for women and higher levels of education attained at the control stage.

The prevalence of hypertension in our present study was 16.3%, which was slightly lower than the 20% found in two previous national representative studies in 2013 and 2020.[10,11] Despite our study not being nationally representative, the numbers presented suggest that rates for Lao PDR likely have not increased as much as in other global regions recently.[4] More generally, Lao PDR's rates are low compared to the global average and SEA region estimates, which is in line with previous findings. A third of adults were found to be hypertensive globally and similar in the urban SEA setting, with Lao PDR among the lowest prevalence of eleven assessed SEA countries.[4,8] These studies generally reported higher rates for women, and higher rates were found in urban settings in Lao PDR specifically,[11] which we did not find in our mutually adjusted models of HT predictors. Previous reports often looked at individual HT predictors not accounting for other potentially relevant factors, which might explain some differences in findings. In agreement with our population's HT increase with BMI, a recent study demonstrated that BMI was positively associated with hypertension prevalence, consistently across the world.[23] We further identified one study exploring predictors in mutually adjusted fashion in Lao PDR, which also found increasing age and BMI to predict hypertension rates.[10] This previous study further found increased alcohol use related to increased HT risk among women, whereas we found a decreased risk for moderate alcohol intake for the whole sample. We did not account for pre-existing health conditions, and individuals who abstained entirely due to such conditions, might have been inherently more at risk for hypertension. We found smoking not to be related to hypertension, similar to a previous Lao PDR study looking at current tobacco use.[10] Similar to our findings, marital status has been found to relate to hypertension risk and related sequelae, with some articles finding widowhood related to increased risks.[28–31]

We found that 60% of hypertensives do not get appropriate treatment in this sample. The biggest losses in the cascade of care were observed at the diagnosis stage, where almost one-third of patients were lost, followed by the treatment stage, where another 20% were lost. Poor hypertension cascade of care performances have been documented widely for LMICs, detailed below. In fact, our study showed improved performance compared to previous reports for SEA and scarce reports for Lao PDR. Drawing conclusions from the following comparisons with previously reported care management rates is, however, not straightforward due to varying methodology such as age standardization or lack thereof and pooling different geographic regions. A recent pooled analysis estimated the rate of being diagnosed at around 36% for SEA countries,[9] while another study estimated it at 54% for men and 45% for women for East Asia and SEA.[4] National representative studies in Lao PDR reported 29.3% of hypertensives were diagnosed among 18- to 64-year olds in 2013[10] and 54.5% among 18 years and older in 2020.[11] The latter included a substantial amount of participants 65 years and older who are generally more often diagnosed (not accounting for other factors), also shown in our present analysis. We found a higher rate of diagnosis of over two-thirds, possibly due to including higher ages, ranging from quadra- to nonagenarians, the urban setting of the Vientiane Capital region, and potential improvements in the local care management.

Similarly, we found over 60% of hypertensives were on HT medication, which suggested a better cascade performance compared to the 2013 and 2020 Lao PDR representative studies, which reported 18.2% and 43.8%, respectively. For wider context, the prevalence of treatment among hypertensives was estimated around a fifth for SEA countries,[9] while another study estimated it at 32% for men and 41% for women for East Asia and SEA.[4] We found a vast majority of hypertensives were ever blood pressure measured by a health professional; other reports on measurement rates among

hypertensives are scarce. One study reported two-thirds of hypertensives were ever measured in SEA, while we found a remarkable 90.2% had been.[9] Finally, we found control rates of almost 40% among hypertensives, which was more than double than estimated for the SEA region[4,9] and markedly higher for Lao PDR reported as 16.7% and 20.3% in two studies.[10,11] Despite differences in methodology outlined above, the increased performance we observed at each step of the care management cascade compared to previous reports could arise from recent improvements in health care and primary prevention efforts. We did not have data to explore such differences between studies further.

To our knowledge, this is the first study in Lao PDR making a comprehensive assessment of predictors of individual cascade steps. For our analysis, we considered factors reported in the literature to be related to hypertension or hypertension care[8–10,22,23,32] and that were available in our study. We found that men were less likely to reach each step of the hypertension care cascade than women, with the biggest difference in being diagnosed and 15% more men being lost in the cascade. Fully adjusted models confirmed that women were indeed significantly more frequently controlled. This is consistent with other studies that documented improved outcomes for women in the hypertension care cascade globally, in SEA and to some extent in Lao PDR.[4,9,11,32,33] Gender-related care-seeking and healthcare utilization, focus of primary health-care services on maternal and child health, and health-care facility operating hours were suggested as reasons for observed sex differences.[9,22,34–38]

We further showed that although women were descriptively more frequently treated for hypertension, there was no statistical difference in their likelihood of achieving blood pressure control (ie among treated women). This aligns with findings from other settings,[22,39,40] indicating the potential need to consider sex-specific strategies for hypertension management due to variations in how the condition presents and progresses. Such targeted programs could engage more men in hypertension screening and care by implementing community outreach campaigns tailored to men's health needs, extending facility operating hours to accommodate work schedules, and offering mobile or workplace-based screening services. Training healthcare providers in sex and gender-sensitive care delivery, integrating related health education into existing community programs, and designing interventions that address men's unique barriers to care while supporting women's continued access to tailored hypertension management could further promote equitable access to resources. We showed HT control status was clearly the worst among the lowest educated, which is in line with other studies showing higher education relating to better control;[9] we found no reports exploring this in Lao PDR. Patients with higher education might manage their condition better, leading to improved blood pressure control. Hypertension management educational programs tailored to individuals with lower levels of education could address such disparate knowledge gaps and thus reduce health inequalities between socioeconomic groups in hypertension care. Specifically, initiatives might prove impactful when incorporating visual aids, interactive community workshops, and culturally appropriate messaging, and when delivered in partnership with local leaders and organizations. While the total cascade losses for retirement age versus not appeared similar, more of the younger participants were lost at the diagnosis stage and more of the older participants at the control stage. This indicates different points to improve by age groups. Policy makers could enhance efforts to diagnose hypertension in younger populations by integrating screenings in workplace health programs while improving adherence among older individuals through community-based support systems, simplified medication regimens, and the provision of written instructions and educational materials to reinforce the importance of lifelong medication adherence. Written instructions specifically were recently shown to improve antihypertensive medication adherence in Lao PDR.[41] Similarly, descriptive results showed that central residents were better controlled over all, but more people were lost at the diagnose stage. This could be related to demographic compositions of the studied areas, as adjusted differences in cascade performance were not significant. Variable access to care might also be relevant but needs to be studied in more detail to be better understood and allow further policy recommendations for improving cascade performance.

In addition to the limitations outlined above, the following ones should be considered for interpreting our results. We utilized cross-sectional data and the results were inherently descriptive and cannot establish causality. The use of a complete case analysis, while consistent with prior studies, resulted in the exclusion of roughly 14% of the eligible participants, mainly due to refusing blood pressure measurement. We found systematic differences in key demographic variables for the excluded, which might have introduced bias. Despite the strength of objectively measured blood pressure levels, other information we used was reported by the participants and is subject to recall and desirability biases. We obtained three blood pressure measurements during the assessment session, but we had no follow-up confirmatory

measurements as recommended in clinical practice,[21] limiting the robustness of our findings. Our treatment definition was limited to drug treatment, and we did not consider or account for primary prevention and lifestyle approaches as this information was not available. While our study provided information on key HT-related factors identified in other studies, our list of potential confounders might not have been exhaustive and we might have missed contributions of unmeasured factors relevant to HT or the HT cascade performance. Specifically, diet such as salt intake or co-morbidities such as raised cholesterol levels were argued to be relevant for HT in Lao PDR in previous studies.[10]

The study sample should be fairly representative of adults over 40 years of age in the Vientiane capital area, as multiple districts with socioeconomic variability, and all newborns and adult relatives therein in a specified time period were included. While our study captured both the wealthiest (Chanthabuly and Sikhottabong) and poorest (Sangthong and Parkngum) districts in the Vientiane region, this selection may underrepresent districts with moderate socioeconomic conditions, potentially limiting the generalizability of our findings to populations falling between these extremes. We further acknowledge that our approach may have missed household members without a recent birth, potentially leading to a slight underrepresentation of certain demographic groups. However, given the broad inclusion of extended family members across diverse districts, we deem the risk of significant bias to be small. Due to the study design, most child-bearing aged women enrolled were pregnant with the index child during our assessments. We excluded all participants below 40 years of age minimizing the presence of pregnancy and potential hypertensive disorders in pregnancy[20] while keeping the sample sex balanced. Therefore, we cannot generalize our findings to younger age groups. Further, Vientiane's urban environment and socioeconomic conditions differ from less developed regions of the country. This potentially leads to inconsistent HT prevalence across regions, which was shown in previous studies in Lao PDR,[11,12] and disparities in access to healthcare, recently demonstrated by evidence on persisting socioeconomic inequities in access to quality care.[42] Consequently, the findings from this study may not fully capture the hypertension landscape or the effectiveness of care in other parts of Lao PDR, limiting the generalizability of our results to the entire country. Interestingly, within Vientiane, we did not observe consistently better care outcomes in the wealthier districts, suggesting that factors beyond socioeconomic status may influence healthcare quality and management of hypertension.

Conclusion

Hypertension rates in the urban and semi-urban areas of Lao PDR currently affect 16% of individuals aged 40 and above; 60% of these cases are currently uncontrolled. Although the Lao PDR health system appears to perform relatively well compared to other LMICs, significant policy efforts are needed to better support this population, improve control rates, and consequently reduce the risk of hypertension-driven cardiovascular diseases and excess mortality in the coming years.

Data Sharing Statement

The dataset used in this study is available from the corresponding author on reasonable request.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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