International Journal of Public Health Science (IJPHS)
Vol. 14, No. 3, September 2025, pp. 1576~1584
ISSN: 2252-8806, DOI: 10.11591/ijphs.v14i3.24980

Prevalence and health literacy on high blood pressure among late adulthood individuals in Northeast Thailand: a cross-sectional study

Kittipong Sornlorm[1], Arunrat Puncha Glingasorn[2]
[1]Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand
[2]Faculty of Liberal Arts and Science, Roi Et Rajabhat University, Roi Et, Thailand

Article Info

Article history:

Received April 21, 2024
Revised Dec 27, 2024
Accepted Mar 6, 2025

Keywords:

Health literacy
High blood pressure
Hypertension prevalence
Late adulthood
Thailand

ABSTRACT

High blood pressure (HBP) is a leading risk factor for atherosclerotic cardiovascular disease and mortality. This study aimed to identify health literacy and other characteristics associated with HBP among late adults in Thailand. A cross-sectional study was conducted with 1,345 adults aged 35-59 years from Health Centers 7, 8, 9, and 10 in Northeast Thailand. Descriptive statistics and a generalized linear mixed model (GLMM) were used to determine the adjusted odds ratio (Adj. OR) and 95% confidence interval (CI). Results showed a prevalence of HBP at 24.76% (95% CI: 22.52-27.13). Multivariable analysis revealed a significant association between HBP and health literacy in finding health information (Adj. OR = 1.59, 95% CI: 1.28-1.96, p-value<0.001), as well as judging health information (Adj. OR = 1.34, 95% CI: 1.04-1.73, p-value=0.024). Additionally, history of smoking (Adj. OR=2.04, 95% CI: 1.29-3.24, p-value = 0.002), comorbidity (Adj. OR = 2.20, 95% CI: 1.76-2.74, p-value <0.001), physical activity (Adj. OR = 1.67, 95% CI: 1.28-2.16, p-value <0.001), and body mass index (Adj. OR = 2.21, 95% CI: 1.14-4.26, p-value=0.018) were found to be associated with HBP. Poor health literacy increases the risk of HBP. Relevant authorities must evaluate the group context and develop a suitable health literacy model.

Corresponding Author:

Kittipong Sornlorm
Faculty of Public Health, Khon Kaen University
Muang District, Khon Kaen, Thailand
Email: kittsorn@kku.ac.th

1. INTRODUCTION

High blood pressure (HBP) is widely recognized as a significant risk factor for cardiovascular diseases [1], [2]. Its prevalence is on the rise globally, with regional variations observed. According to global estimates, by 2025, approximately 31.1% (1.39 billion) of the late adult population worldwide is projected to be affected by HBP [3], [4], with this figure expected to increase to approximately 60% of the global population [5].

According to recent global analysis, Thailand, as part of the East and Southeast Asia region, shows moderate rates of hypertension detection, treatment, and control. In 2019, the regional data indicated that 54% (46-62%) of people with hypertension had been diagnosed, 41% (32-49%) were receiving treatment, and only 17% (13-25%) achieved adequate blood pressure control. While global hypertension prevalence remained stable from 1990 to 2019 at approximately 32-34% in adults aged 30-79 years, significant improvements in treatment and control rates have been observed in many middle-income countries, though substantial gaps remain in detection and management across different regions [6]. The number of deaths

attributable to HBP tends to increase alongside the rise in the number of patients [7]. Health indices reveal that the northeastern region of Thailand demonstrates a heightened risk of HBP, characterized by low levels of high-density lipoprotein cholesterol (HDL-C) and high triglycerides, which in turn elevate the likelihood of developing HBP. This underscores a notable upward trend in the prevalence of HBP within the region [8].

While the prevalence and factors associated with HBP have been extensively studied in the elderly population, there is a notable gap in research focusing on late adulthood individuals in Northeast Thailand. This gap highlights the need for further investigation in this area. Given that late adulthood marks the onset of hypertension for many individuals, it is imperative to develop blood pressure disease prevention strategies tailored to this demographic in Thailand. Within four years, two-thirds of untreated cases of prehypertension might develop into hypertension [9]. The late adult population is facing lifestyle-related risk factors, including improper diet, lack of exercise, stress, heavy responsibilities, and inadequate attention to regular health monitoring. Significant research has revealed that in addition to hereditary variables, lifestyle changes, and behavioral characteristics are primary causes of HBP [10], lack of exercise, body mass index (BMI), low income, smoking, and drinking alcohol [11]. Adequate health literacy can lead to informed decision-making in health promotion, disease prevention, and the improvement of personal quality of life [12].

Currently, there is limited empirical research focusing on prehypertension and hypertension in late adulthood, often neglecting age-specific contexts. This study investigates health literacy factors among late adults in Northeast Thailand to guide context-appropriate health promotion strategies and mitigate hypertension-related complications. Therefore, this study aimed to determine the prevalence of HBP and explore the health literacy and factors associated with HBP among late adulthood individuals residing in the northeastern region of Thailand.

2. METHOD

2.1. Study design

This is a pilot, cross-sectional, and descriptive study, focusing on a specific demographic of adults aged between 35 and 59 years old. Data were collected at Regional Health Centers 7, 8, 9, and 10 in the Northeastern region of Thailand from January to March 2023. The study population was late adults in Northeastern Thailand with an age range of 35-59 years. The study aims to investigate the variables associated with HBP in the working adult population residing in Northeast Thailand.

The researchers employed probability sampling to select participants from northeastern Thailand. Four regional health systems, numbered 7, 8, 9, and 10, were included in the sampling process. The criteria for blood pressure measurements were taken according to the guidelines outlined in the seventh report of the Joint National Committee (JNC7). Blood pressure was classified into four categories based on systolic blood pressure (SBP) and diastolic blood pressure (DBP): i) Normal blood pressure (SBP<120 mmHg and DBP<80 mmHg); ii) Pre-hypertension (SBP 120–139 mmHg and/or DBP 80–89 mmHg); iii) Stage 1 hypertension (SBP 140–159 mmHg and/or DBP 90–99 mmHg); and iv) Stage 2 hypertension (SBP≥160 mmHg and/or DBP≥100 mmHg). Then, HBP was considered when the average SBP of at or above SBP of≥140 mmHg and/or DBP of ≥ 90 mmHg. The sample size of 1,345 was calculated using a multiple regression sample size formula [13], based on previous research that identified significant associations between health literacy and hypertension as demonstrated in Figure 1 [14]. Total participants=risk group of Pre-HT+Patient of hypertension.

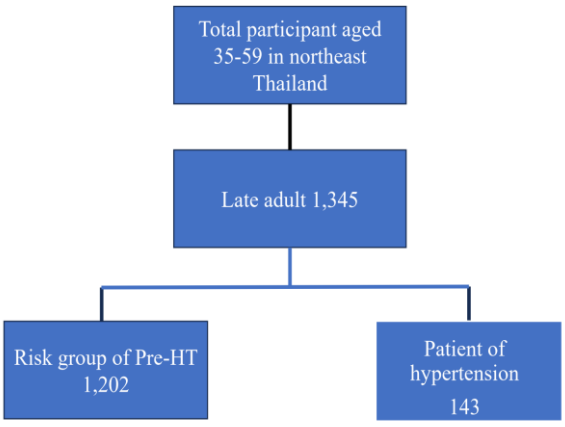

Figure 1. Flow diagram showing the number of participants in study

2.2. Instruments of the study

The study employed closed-ended, self-administered questionnaires. A modified version of the questionnaire was used, comprising six sections: i) demographic information, including age, gender, income, and education level, ii) health literacy, based on the HLS-EU-Q47 self-administered questionnaire [15], and iii) depression, adapted from the Department of Mental Health, Thailand. To ensure validity, the questionnaire was reviewed by five experts in the field, achieving an item-objective congruence score of 0.92. Additionally, the study focused on three constructs—health literacy and depression—yielding Cronbach's alpha coefficients of 0.94 and 0.82, respectively.

Health literacy (HL) in this study was assessed through a comprehensive 45-item test covering four essential components: accessing/obtaining, understanding, evaluating, and utilizing health information. Each item was rated on a four-point ordinal scale, ranging from "very difficult" to "very easy." Participants were categorized into four groups—inadequate, problematic, sufficient, and excellent—based on their scores, which were assigned according to predefined ranges and corresponding classifications for each group.

The research employed the six-part patient health questionnaire-9 (PHQ-9) to evaluate the frequency and severity of depressive symptoms over a 14-day period, as well as to determine the likelihood of depression [16]. The PHQ-9 utilizes a 4-point Likert scale, ranging from 0 (indicating the absence of an event) to 3 (indicating an event occurring nearly every day), resulting in a total score ranging from 0 to 27. This questionnaire is widely recognized and respected on an international scale. Blood pressure measurement was conducted using automatic blood pressure (ABP) monitors. Final blood pressure readings for the subjects were recorded as the mean of the second and third measurements. Hypertension (HBP) classification was determined according to the criteria outlined in the seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure (JNC7) [17].

2.3. Data and descriptive statistics

Data analyses were conducted using STATA statistical version 18. Descriptive statistics, including percentages, minimum and maximum values, means, standard deviations (SDs), and medians, were employed to analyze demographic data, environmental factors, health literacy, and depression. A generalized linear mixed model (GLMM) was utilized to account for random effects and correlations within clusters [18]. In this modeling, residential regional health was designated as the random effect. Bivariate analysis was initially conducted to explore the associations between each independent variable and HBP. Variables showing significance in the bivariate analysis (p-value<0.25) were then included in the multivariable analysis. In the final model using backward elimination, which retained only significant factors, the outcomes elucidate the extent of association between independent variables and HBP, presented as adjusted odds ratios (ORs) alongside their corresponding 95% confidence intervals (CIs).

3. RESULTS

3.1. Sociodemographic characteristics, health literacy, depression of late adulthood with HBP

The majority of the 1,345 participants were female (67.06%) and aged between 40-44 years. Most participants were married and cohabiting (73.68%), with 43.79% having primary school education. More than half (53.0%) were engaged in agriculture, while 83.72% reported never smoking. A third of the participants had comorbidities (20.74%). Among all participants, 540 individuals reported no physical activity (40.15%) and 41.19% were obese. Half of the participants demonstrated sufficient health literacy (61.12%) and non-depression (84.31%) as shown in Table 1.

3.2. Prevalences of HBP among late adulthood individuals in the Northeast of Thailand

Table 2 provides an overview of the prevalence of HBP among late adulthood individuals, those at risk of pre-hypertension (PreHT), and patients with hypertension. Among the late adult population (1,345 individuals), 75.24% were categorized as normal, while 24.75% were identified with HBP (≥140/≥90). In the PreHT risk group (1,202 individuals), 82.94% were classified as normal, and 17.05% had HBP. Among patients with hypertension (143 individuals), 62.24% were categorized as normal, while 37.76% were identified with HBP. Each percentage is accompanied by its corresponding 95% confidence interval (CI).

3.3. Bivariate analysis for the risk factors of HBP among late adulthood individuals

The bivariate analysis, presented in Table 3, outlines the factors associated with HBP among participants. In the initial multivariable analysis model, factors with p-values less than 0.25 were included. These factors comprised gender, age, marital status, occupation, smoking habits, comorbidities, physical activity, and health literacy.

Table 1. Sociodemographic characteristics, health literacy, depression (n = 1,345)

Variable		Number	Percentage (%)
Gender	Female	902	67.06
	Male	443	32.94
Age	35-39	248	18.44
	40-44	336	24.98
	45-49	295	21.93
	50-54	251	18.66
	55-59	215	15.99
Status	Single	234	17.40
	Married/co-inhabiting	991	73.68
	Separated/divorced/widowed	120	8.92
Educational	Illiterate	9	0.67
	Primary school	589	43.79
	High school	386	28.70
	Diploma	69	5.13
	College	126	9.37
	Master's degree or higher	166	12.34
Occupational	Unemployed	34	2.53
	Agriculturist	73	53.01
	Private business	130	9.67
	Government employee	270	20.07
	Officer	55	4.09
	Housewife	47	3.49
	Employed	96	7.14
Current smoking	Never	1,126	83.72
	Ex-smoker	73	5.43
	Current smoker	146	10.86
Comorbidity	No	1,066	79.26
	Yes	279	20.74
Physical activity	Yes	805	59.85
	No	540	40.15
BMI (kg/m2)	Underweight	48	3.57
	Normal	465	34.57
	Overweight	278	20.67
	Obesity	554	41.19
Health literacy (total)	Inadequate (0-50%)	34	2.53
	Problematic (51-66%)	271	2015
	Sufficient (67-84%)	822	61.12
	Excellent (≥85%)	218	16.21
HL finding health information (FHI)	Inadequate (0-50%)	75	5.58
	Problematic (51-66%)	228	16.95
	Sufficient (67-84%)	793	58.96
	Excellent (≥85%)	249	18.51
HL understanding health information (UHI)	Inadequate (0-50%)	31	2.30
	Problematic (51-66%)	48	3.59
	Sufficient (67-84%)	854	63.83
	Excellent (≥85%)	412	30.79
HL judging health information (JHI)	Inadequate (0-50%)	28	2.08
	Problematic (51-66%)	157	11.67
	Sufficient (67-84%)	879	65.35
	Excellent (≥85%)	281	20.89
HL applying health information (AHI)	Inadequate (0-50%)	15	1.12
	Problematic (51-66%)	85	6.32
	Sufficient (67-84%)	836	62.16
	Excellent (≥85%)	409	30.41
Depression	None (<7)	1,134	84.33
	Mild (7-12)	56	4.16
	Moderate (13-18)	137	10.19
	Severe (≥19)	18	1.34

*BMI was redefined into 4 categories due to low numbers of underweights (normal weight 18.5-22.99 kg/m^2, overweight 23.0-24.99 kg/m^2, and obesity ≥25.0 kg/m^2

Table 2. Prevalence of HBP among late adulthood individuals

Factors	Number (%)	95%CI
Late adult (1,345)		
Normal	1,012 (75.24)	72.86-77.47
HBP (≥140/≥90)	333 (24.75)	22.52-27.13
Risk group of PreHT (1,202)		
Normal	997 (82.94)	80.70-84.97
HBP (≥140/≥90)	205 (17.05)	15.02-19.29
Patient of hypertension (143)		
Normal	89 (62.24)	53.92-69.88
HBP (≥140/≥90)	54 (37.76)	30.11-46.07

Table 3. The bivariate analysis examined the risk factors associated with HBP among late adulthood individuals (n=1,345)

Variables	Number	% of HBP	Crude odds ratio	95%CI	p-value
Gender					0.091
Female	902	17.18	1		
Male	443	20.99	1.28	0.96-1.70	
Age					0.063
<50	584	22.26	1		
≥50	761	26.68	1.27	0.14-0.34	
Status					*0.019
Single	23	20.51	1		
Married/Co-Inhabiting	991	26.64	1.40	1.00-1.99	
Separated/Divorced/Widowed	120	17.50	0.82	0.46-1.45	
Educational					***0.002**
College/master's degree or higher	292	20.89	1		
High school/diploma	455	21.32	1.02	0.71-1.47	
Illiterate/primary school	598	29.26	1.56	1.12-2.18	
Occupational					0.072
Unemployed/housewife	81	24.69	1		
Agriculturist	713	27.49	1.15	0.67-1.96	
Private business/employed	226	22.57	0.88	0.49-1.60	
Government employee/officer	325	20.31	0.77	0.43-1.37	
Current smoking					*<0.001
Never	756	22.74	1		
Ex-smoker	114	45.21	2.80	1.73-4.53	
Current smoker	475	30.14	1.46	1.00-2.14	
Comorbidity					*<0.001
No	1,066	21.48	1		
Yes	279	37.28	2.17	1.63-2.88	
Physical activity					*0.001
Yes	805	21.61	1		
No	540	29.44	1.51	1.17-1.94	
BMI					*<0.001
Normal	513	16.18	1		
Overweight/obese	832	30.05	2.22	1.68-2.93	
Health literacy(total)					0.086
Sufficient/excellent	1,040	23.65	1		
Inadequate/problematic	305	28.52	1.28	0.96-1.71	
HL finding health information (FHI)					*0.001
Sufficient/excellent	1,042	19.80	1		
Inadequate/problematic	303	26.20	1.57	1.18-2.08	
HL understanding health information (UHI)					0.093
Sufficient/excellent	1,266	24.25	1		
Inadequate/problematic	79	32.91	1.53	0.94-2.49	
HL judging health information (JHI)					0.826
Sufficient/excellent	1,160	24.66	1		
Inadequate/problematic	185	25.41	1.04	0.72-1.48	
HL applying health information (AHI)					0.089
Sufficient/excellent	1,245	24.18	1		
Inadequate/problematic	100	32.00	1.47	0.95-2.29	
Depression					0.388
None/mild	1,190	24.71	1		
Moderate	137	23.36	0.92	0.61-1.40	
Severe	18	38.89	1.93	0.74-5.04	

Note: *Significantly associated with HBP.

3.4. Multivariable analysis of factor associated with HBP by using the GLMM

The multivariable analysis for associated factors of HBP was identified by using the GLMM to control the clustering effect of the sampling selection of the participants. In the final model, HL finding health information, HL judging health information, smoking, comorbidity, physical activity, and BMI remained significantly associated with HBP. Participants with inadequate and problematic HL finding health information were more likely to have HBP than those with sufficient and excellent HL in this area (Adj. OR = 1.59, 95% CI: 1.28-1.96, p-value<0.001). Similarly, participants with inadequate and problematic HL judging health information were more likely to have HBP than those with sufficient and excellent HL judging health information (Adj. OR = 1.34, 95% CI: 1.04-1.73, p-value = 0.024). The odds of having HBP were almost 2 times higher among comorbidity participant compare to non- comorbidity participant (Adj. OR=2.21, 95% CI: 1.54-2.83, p-value = 0.018), Overweight or obese participants were significantly more likely to suffer from HBP (Adj. OR = 2.21, 95% CI: 1.54-2.83, p-value = 0.018). Those who ever smoked and current smoker consumption had a higher risk of HBP than participants who never smoked use

(Adj. OR = 2.04, 95% CI: 1.29-3.24, p-value = 0.002). Physical activity was significantly associated with HBP. (Adj. OR = 1.67, 95% CI: 1.28-2.16, p-value<0.001) as shown in Table 4.

Table 4. Multivariable analysis of factor associated with HBP by using the GLMM

Factors	Number	% of HBP	Crude Odds Ratio	Adj. Odds Ratio	95%CI	p-value
HL finding health information (FHI)						<0.001
Sufficient /Excellent	1,042	19.80	1			
Inadequate/ Problematic	303	26.20	1.57	1.59	1.28-1.96	
HL judging health information (JHI)						0.024
Sufficient /Excellent	1,160	24.66	1			
Inadequate/ Problematic	185	25.41	1.04	1.34	1.04-1.73	
Current smoking						0.002
Never	1,126	22.74	1			
Ex-smoker /Current smoker	219	35.16	1.84	2.04	1.29-3.24	
Comorbidity						<0.001
No	1,066	21.48	1			
Yes	279	37.28	2.17	2.20	1.76-2.74	
Physical activity						
Yes	805	21.61	1			<0.001
No	540	29.44	1.51	1.67	1.28-2.16	
BMI (kg/m^2)						0.018
Low/normal (<23)	513	16.18	1			
Over weight (23-24.99)/Obesity (≥25)	832	30.05	2.22	2.21	1.14-4.26	

4. DISCUSSION

The study reported a 24.75% prevalence of HBP among late adults in Northeast Thailand, a figure comparable to sub-Saharan Africa's 28% [19]. However, this rate exceeds that found in South Asia, where HBP affects 14.9% of older adults in India, 19.8% in Bangladesh, and 13.8% in Nepal [6]. Such variation may reflect differences in lifestyle, genetic predisposition, or healthcare accessibility across these regions. These findings underscore a significantly higher prevalence in Thailand compared to previous regional studies and highlight the urgent need for targeted interventions. In the realm of health literacy concerning information utilization, it has been demonstrated that individuals with inadequate or problematic information encounter difficulties in effectively managing HBP. The p-value of <0.001 obtained in this study is deemed statistically significant. These findings are consistent with those reported by Sundell *et al.* [20] indicating a correlation between access to personal health information and good health literacy. Essentially, individuals lacking access to health information may struggle to manage their own health effectively. Specifically, inadequate/problematic health literacy judging health information (HLJHI) resulted in a 1.34 times higher risk of high blood pressure compared to late adults with adequate or excellent health literacy levels. Notably, late adulthood in the Northeast region exhibits the highest proportion of individuals with less than a bachelor's degree, potentially leading to reduced engagement in health-related decision-making. This observation resonates with the findings of Aboumatar *et al.* [21], highlighting significant differences in treatment decision participation between hypertensive patients with low education and health literacy levels and their literate counterparts.

The results of this research, indicating that individuals who currently smoke or have ever smoked are at a higher risk of developing HBP, are consistent with previous findings reported by Esteche *et al.* [22]. In their study involving 391 hypertensive patients, smoking was found to be associated with elevated blood pressure levels during sleep [23]. Conversely, Gao *et al.* [24] found no significant difference in hypertension risk between current tobacco users and non-smokers. However, heavy machine-rolled cigarette smoking significantly increased hypertension risk, likely due to toxins causing vascular stiffening, thus impacting blood pressure regulation.

The study revealed that participants with comorbid diseases were more susceptible to developing HBP compared to individuals without any comorbidities. This association is attributed to the additional strain placed on the heart and arteries due to underlying health conditions. As a result, the heart must work harder, leading to stiffening and potential rupturing of arteries, thereby increasing blood pressure. These findings align with those of Das *et al.* [25] observed a 2.65 times increased risk of HBP in individuals with morbid obesity. Furthermore, Wandile emphasized the importance of maintaining normal blood pressure levels to prevent severe complications associated with comorbid conditions [26].

The study highlights the significant association between physical activity and blood pressure levels, with ample supporting evidence suggesting that exercise aids in dilating blood vessels, a consistent finding across previous studies. For instance, Syauqi [27] observed in their study on physical activity among hypertensive patients that it led to a reduction in systolic blood pressure (SBP) levels. Additionally, Gamage

and Seneviratne [28] identified lack of exercise as a risk factor for high blood pressure among employees. Moreover, Yang *et al.* [29] demonstrated that physical fitness serves as a preventive factor against hypertension in adults, reinforcing the protective effects of exercise.

The positive associations observed in this survey between HBP and a BMI of 25 or more align with findings from previous studies. For example, Rahut *et al.* [23] discovered that overweight and obese groups in Bangladesh had a higher risk of developing high blood pressure compared to those with a normal BMI. Similarly, Mamdouh *et al.* [30] found that the overweight group had a 2.56 times higher likelihood of developing high blood pressure than the normal weight group. This relationship between increased BMI and HBP in late adulthood may be attributed to elevated fatty tissue levels in obese individuals, which can lead to increased vascular resistance and subsequently increase the workload required for the heart to pump blood throughout the body.

This study represents the first investigation in Northeastern Thailand to examine the prevalence of HBP and its relationship with health literacy and other influencing factors. The findings highlight a significant connection between health literacy, blood pressure levels, and various potential risk factors. These results provide a valuable reference for policymakers and researchers in developing effective public health strategies and advancing future research to enhance well-being. However, the study has certain limitations, particularly its cross-sectional design, which limits the ability to determine causal relationships between risk factors and HBP.

5. CONCLUSION

In conclusion, the study reveals a concerning prevalence of HBP among late adults in Northeast Thailand, surpassing rates reported in neighboring South Asian countries. This underscores the urgent need for targeted interventions to address the multifaceted determinants of HBP in the region. Enhancing health literacy, particularly in accessing and interpreting health information, is paramount to empowering individuals in managing their health effectively. Efforts to reduce smoking rates and promote healthier lifestyle choices, such as regular physical activity and weight management, are crucial to mitigating HBP risk. Moreover, interventions targeting comorbidities and providing support for individuals with existing health conditions are essential for HBP prevention and management. By adopting a comprehensive approach that integrates education, lifestyle modification, and healthcare support, stakeholders can work towards reducing the burden of HBP and improving cardiovascular health outcomes among late adults in Northeast Thailand.

ACKNOWLEDGMENTS

We sincerely appreciate all participants for dedicating their time and contributing invaluable insights, without which this study would not have been feasible.

FUNDING INFORMATION

This study was funded by the 2023 Research Grant from the Faculty of Public Health, which supports faculty research staff. The grant is part of a strategic initiative of the Faculty of Public Health at Khon Kaen University. The funding body had no involvement in any aspect of this research.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration. K.S. was responsible for conceptualization, while K.S. and A.G. jointly conducted the investigation, data curation, and the writing and editing processes. K.S. secured the funding, verified the accuracy of the study, and provided guidance to ensure the results aligned with the research objectives. All authors discussed the findings and contributed to the final manuscript.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Kittipong Sornlorm	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Arunrat Puncha				✓	✓	✓		✓	✓	✓	✓			
Glingasorn														

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors have declared that no competing interests exist.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee. The research received approval from the Institutional Review Board of Khon Kaen University (HE652233). Participants' autonomy was respected, with each individual providing written informed consent. To protect their privacy, pseudonyms were assigned, and measures were taken to ensure the confidentiality of the collected data.

DATA AVAILABILITY

All relevant data are within the paper and its supporting information files.

REFERENCES

[1] M. D. Saju, K. P. Allagh, L. Scaria, S. Joseph, and J. A. Thiyagarajan, "Prevalence, awareness, treatment, and control of hypertension and its associated risk factors: Results from baseline survey of SWADES family cohort study," *International Journal of Hypertension*, vol. 2020, pp. 1–7, Apr. 2020, doi: 10.1155/2020/4964835.

[2] World Health Organization, "Global Health Observatory data repository: Prevalence rate of hypertension in adults aged 30-79 years," 2024. https://www.who.int/data/gho (accessed Jan. 03, 2025).

[3] K. T. Mills *et al.*, "Global disparities of hypertension prevalence and control," *Circulation*, vol. 134, no. 6, pp. 441–450, Aug. 2016, doi: 10.1161/CIRCULATIONAHA.115.018912.

[4] B. Zhou *et al.*, "Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants," *The Lancet*, vol. 398, no. 10304, pp. 957–980, Sep. 2021, doi: 10.1016/S0140-6736(21)01330-1.

[5] P. M. Kearney, M. Whelton, K. Reynolds, P. Muntner, P. K. Whelton, and J. He, "Global burden of hypertension: analysis of worldwide data," *The Lancet*, vol. 365, no. 9455, pp. 217–223, Jan. 2005, doi: 10.1016/S0140-6736(05)17741-1.

[6] B. Zhou *et al*., "Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants," *The Lancet*, vol. 398, no. 10304, pp. 957–980, 2021, doi: 10.1016/S0140-6736(21)01330-1."Health Data Center." https://hdcservice.moph.go.th (accessed Jan. 10, 1BC).

[7] Department of Disease Control. [Online]. Available at: https://ddc.moph.go.th/disease_detail.php. Accessed January 1st, 2023.

[8] W. Aekplakorn, "Thai national health examination survey 5th (NHES) in 2014 health systems research institute (HSRI)," *Nontaburi Publishers*, p. 166, 2014.

[9] S. Julius *et al.*, "Feasibility of treating prehypertension with an angiotensin-receptor blocker," *New England Journal of Medicine*, vol. 354, no. 16, pp. 1685–1697, Apr. 2006, doi: 10.1056/NEJMoa060838.

[10] E. Grossman, "Ambulatory blood pressure monitoring in the diagnosis and management of hypertension," *Diabetes Care*, vol. 36, no. Supplement_2, pp. S307–S311, Aug. 2013, doi: 10.2337/dcS13-2039.

[11] R. M. Carey, P. Muntner, H. B. Bosworth, and P. K. Whelton, "Prevention and control of hypertension," *Journal of the American College of Cardiology*, vol. 72, no. 11, pp. 1278–1293, Sep. 2018, doi: 10.1016/j.jacc.2018.07.008.

[12] K. Sørensen *et al.*, "Health literacy in Europe: comparative results of the European health literacy survey (HLS-EU)," *The European Journal of Public Health*, vol. 25, no. 6, pp. 1053–1058, Dec. 2015, doi: 10.1093/eurpub/ckv043.

[13] F. Y. Hsieh, D. A. Bloch, and M. D. Larsen, "A simple method of sample size calculation for linear and logistic regression," *Statistics in Medicine*, vol. 17, no. 14, pp. 1623–1634, Jul. 1998, doi: 10.1002/(SICI)1097-0258(19980730)17:14<1623::AID-SIM871>3.0.CO;2-S.

[14] K. T. Selcuk, Y. Mercan, and T. Aydin, "Uncontrolled blood pressure in patients with hypertension and associated factors: The role of low health literacy," *Erciyes Tıp Dergisi/Erciyes Medical Journal*, vol. 40, no. 4, pp. 222–227, Dec. 2018, doi: 10.5152/etd.2018.18102.

[15] K. Sørensen *et al.*, "Health literacy in Europe: comparative results of the European health literacy survey (HLS-EU)," *The European Journal of Public Health*, vol. 25, no. 6, pp. 1053–1058, Dec. 2015, doi: 10.1093/eurpub/ckv043.

[16] M. Lotrakul, S. Sumrithe, and R. Saipanish, "Reliability and validity of the Thai version of the PHQ-9," *BMC Psychiatry*, vol. 8, no. 1, p. 46, Dec. 2008, doi: 10.1186/1471-244X-8-46.

[17] A. V. Chobanian *et al.*, "Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure," *Hypertension*, vol. 42, no. 6, pp. 1206–1252, Dec. 2003, doi: 10.1161/01.HYP.0000107251.49515.c2.

[18] C. E. McCulloch and S. R. Searle, *Generalized, Linear, and Mixed Models*. Wiley, 2000. doi: 10.1002/0471722073.

[19] P. Jeemon *et al*., "World heart federation roadmap for hypertension – A 2021 Update," *Global Heart*, vol. 16, no. 1, Sep. 2021, doi: 10.5334/gh.1066.

[20] E. Sundell, J. Wångdahl, and Å. Grauman, "Health literacy and digital health information-seeking behavior – a cross-sectional study among highly educated Swedes," *BMC Public Health*, vol. 22, no. 1, p. 2278, Dec. 2022, doi: 10.1186/s12889-022-14751-z.

[21] H. J. Aboumatar, K. A. Carson, M. C. Beach, D. L. Roter, and L. A. Cooper, "The impact of health literacy on desire for participation in healthcare, medical visit communication, and patient reported outcomes among patients with hypertension," *Journal of General Internal Medicine*, vol. 28, no. 11, pp. 1469–1476, Nov. 2013, doi: 10.1007/s11606-013-2466-5.

[22] V. T. Esteche, P. Sposito, C. Acosta, M. Pereda, and E. Soto, "Association between smoking and hypertension control: descriptive and analytical study," in *Tobacco, smoking control and health education*, Sep. 2021, p. PA2443. doi: 10.1183/13993003.congress-2021.PA2443.
[23] D. B. Rahut, R. Mishra, T. Sonobe, and R. R. Timilsina, "Prevalence of prehypertension and hypertension among the adults in South Asia: A multinomial logit model," *Frontiers in Public Health*, vol. 10, Jan. 2023, doi: 10.3389/fpubh.2022.1006457.
[24] N. Gao *et al.*, "Assessing the association between smoking and hypertension: Smoking status, type of tobacco products, and interaction with alcohol consumption," *Frontiers in Cardiovascular Medicine*, vol. 10, Feb. 2023, doi: 10.3389/fcvm.2023.1027988.
[25] S. Das, M. Debnath, S. Das, S. Sarkar, and A. S. Rumana, "Association of overweight and obesity with hypertension, diabetes and comorbidity among adults in Bangladesh: evidence from nationwide demographic and health survey 2017–2018 data," *BMJ Open*, vol. 12, no. 7, p. e052822, Jul. 2022, doi: 10.1136/bmjopen-2021-052822.
[26] P. M. Wandile, "Hypertension and comorbidities: A silent threat to global health," *Hypertension and Comorbidities*, vol. 1, no. 1, pp. 1–7, 2024, doi: 10.46439/hypertension.1.001.
[27] K. R. Syauqi, "Physical activity effect on blood pressure of hypertensive patients in Kalideres, Jakarta," *Journal of Hypertension*, vol. 39, no. Supplement 2, pp. e4–e5, May 2021, doi: 10.1097/01.hjh.0000752412.72152.d5.
[28] A. U. Gamage and R. de A. Seneviratne, "Physical inactivity, and its association with hypertension among employees in the district of Colombo," *BMC Public Health*, vol. 21, no. 1, p. 2186, Dec. 2021, doi: 10.1186/s12889-021-12013-y.
[29] J. Yang *et al.*, "Association between push-up exercise capacity and future cardiovascular events among active adult men," *JAMA Network Open*, vol. 2, no. 2, p. e188341, Feb. 2019, doi: 10.1001/jamanetworkopen.2018.8341.
[30] H. Mamdouh *et al.*, "Prevalence and associated risk factors of hypertension and pre-hypertension among the adult population: findings from the dubai household survey, 2019," *Journal of Hypertension*, vol. 40, no. Suppl 1, p. e229, 2022, doi: 10.1097/01.hjh.0000837816.80236.53.

BIOGRAPHIES OF AUTHORS

Kittipong Sornlorm is a lecturer of Biostatistics and Geoinformatics in Faculty of Public Health Khon Kaen University. He has published over ten peer-reviewed scientific articles in major journals on the subjects of public health and spatial distribution. He can be contacted at email: kittsorn@kku.ac.th.

Arunrat Puncha Glingasorn is a lecturer of public health in Faculty of Liberal Arts and Science, Roi Et Rajabhat University. Her received her Ph.D. from Khon Kaen University. She also completed her master's degree in public health administration program at Khon Kaen University. Her research focuses on public health and traditional medicine. She can be contacted at email: arupuncha7@gmail.com.