**Prevalence and Risk Factors for** **Hypertension, Diabetes, and Hypercholesterolemia Across the Six Southeast Asian Regions**

**Summary**

**Background**

Non-communicable diseases (NCDs) stand as the primary cause of morbidity and mortality globally and pose an increasingly significant health burden. This study examined the prevalence of hypertension, diabetes, and hypercholesterolemia across the Southeast Asian Regions (SEAR) and explored their behavioral and biological risk factors.

**Methods**

We analyzed the most recent WHO STEPwise approach to NCD risk factor surveillance (STEPS) survey data from the six SEARs using a cross-sectional study approach. Initially, we used cross-tabulation, Chi-square tests, and logistic regression models to evaluate the prevalence of NCDs and their associations with different risk factors across various countries and with the pooled dataset of this region.

**Findings**

This study found the prevalence of hypertension, diabetes, and hypercholesterolemia highest in Timor-Leste (39.70%), Bangladesh (8.71%), and Myanmar (34.40%), respectively. Conversely, lower rates were noted in Maldives (18.01%), Timor-Leste (1.15%), and Nepal (11.13%), respectively. The pooled analysis conducted in these countries revealed prevalence rates of 27.39% for hypertension, 5.69% for hyperglycemia, and 31.21% for hypercholesterolemia in the region. This prevalence is notably higher among individuals aged 60 years or older compared to those of younger age. Engaging in vigorous activities during work appears to be associated with lower NCD rates in contrast to those who have not participated in such activities. Moreover, obesity appears to be a significant risk factor, with higher rates observed among obese individuals in comparison to their non-obese counterparts. Additionally, several other factors exhibit significant associations with NCD prevalence, including gender, level of education, marital status, employment status, dietary habits such as excessive salt consumption and frequent use of oil, eating meals outside the home, engagement in moderate physical activity at work, active commuting, and participation in vigorous leisure activities.

**Interpretation**

The study highlighted a concerning growth in NCDs' prevalence and their associated risk factors within certain SEARs. It underscores the imperative for concerted efforts to develop comprehensive national action plans aimed at addressing the burden of NCDs.

**Funding** None.

**Research in context**

**Evidence before this study**

According to WHO (2020), noncommunicable diseases (NCDs) are a major and increasing burden in the South-East Asia Region, causing 62% of all deaths, or 9 million people. Premature mortality from NCDs, occurring before age 70, is particularly concerning. In 2021, NCDs accounted for approximately two-thirds of all deaths in WHO SEARs, with half of these fatalities occurring among individuals aged 30–69 years. By 2021, ten countries in the region had developed comprehensive national action plans for NCDs, aligning with the Sustainable Development Goal (SDG) 3.4 targeting a 33.3 % reduction of premature NCD mortality by 2030.

A PubMed search on December 31, 2023, using terms related to NCDs and Southeast Asia, found studies limited to specific areas and NCDs among the adult population in South and Southeast Asia. However, no study provided both a country-wise comparison and a pooled analysis to represent the regional scenario and associated risk factors. This study aims to examine the epidemiological patterns and determinants of behavioral and biological risk factors for several NCDs, using both country-wise and pooled data in SEARs.

**Added value of this study**

This study is the first in Southeast Asian regions to utilize nationwide survey data for estimating NCD prevalence differences and associated risk factors. Higher rates of hypertension, diabetes, and hypercholesterolemia were observed in Timor-Leste (39.30%), Bangladesh (8.30%), and Myanmar (36.70%), respectively, while lower rates were noted in Maldives (19.07%), Timor-Leste (1.50%), and Nepal (11.19%), respectively. Pooled analysis across these countries revealed prevalence rates of 28.76% for hypertension, 5.76% for hyperglycemia, and 32.15% for hypercholesterolemia. These rates were notably higher among individuals aged 60 years or older. Vigorous activities during work were associated with lower NCD rates, while obesity emerged as a significant risk factor for causing higher NCD rates. Additional factors such as gender, education level, marital status, employment status, dietary habits, physical activity, and commuting patterns also showed significant associations with NCD prevalence.

**Implications of all the available evidence**

Since the adoption of the 2011 UN High-level Political Declaration, Southeast Asian countries have prioritized strengthening primary healthcare systems to tackle NCDs. Regional commitments such as the 2013 Delhi Declaration on high blood pressure, 2015 Dili Declaration on tobacco, and 2016 Colombo Declaration on NCDs at the primary healthcare level guide national actions for risk prevention and management. Common risk factors in the region include poor diet, tobacco use, physical inactivity, and abdominal obesity. The study recommends individual and collective interventions, focusing on the elderly, female, and urban populations, to inform comprehensive national action plans. Population-based primary healthcare approaches are crucial for risk reduction, detection, and treatment. Hospital-based strategies should also address diagnosed cases of hypertension and diabetes. Non-health sectors should participate in preventive efforts, targeting specific demographics and considering urban-rural disparities and socioeconomic status.

**Introduction**

Non-communicable diseases (NCDs), such as cardiovascular diseases, cancer, respiratory conditions, and diabetes mellitus, persist over time due to a complex interplay of genetic, physiological, environmental, and behavioral risk factors 1. Furthermore, these diseases are progressively emerging as prominent factors contributing to morbidity and mortality in low- and middle-income countries (LMICs) 2–5. As per the World Health Organization (WHO) assessments, NCDs account for 71% of total global fatalities. Approximately 85% of premature deaths in LMICs, and within this demographic, 61% of the deaths affect individuals below the age of 70 6. In 2012, NCDs led to a total of 277,500 fatalities, equating to a mortality rate of 564.1 per 100,000 in males and 531.9 per 100,000 in females 7. Numerous conducted studies have determined that socio-demographic characteristics play a role in the variation of NCD risk factors. In addition, according to WHO’s Global Health Risks Report, the primary global risk factor for NCDs in terms of attributable deaths is hypertension, responsible for 13% of global fatalities. Tobacco use (9%), diabetes (6%), physical inactivity (6%), and overweight/obesity (5%) are notable risk factors.

The risk factors associated with these significant NCDs are extensively documented and commonly shared by WHO 1. In LMICs, a notable increase in NCD risk factors is attributed to behavioral (smoking, alcohol, unhealthy diet, physical inactivity) and biological factors (elevated BP, blood glucose, cholesterol, overweight) 8,9. Furthermore, the likelihood of NCDs advancing is noted to escalate when multiple risk factors coexist in an individual, a phenomenon termed clustering 10. The World Health Report 2002 emphasized the importance of concentrating on risks and risk factors for both assessment and interventions. In the adult population of the South Asian Region (SAR), there is a clustering of risk factors for NCDs, and this clustering becomes more apparent as individuals age. In the SAR, cardiovascular diseases (CVDs), cancer, diabetes, and chronic respiratory diseases, primarily, pose a significant and escalating challenge to health and development 11. In Bangladesh, Bhutan, Myanmar, Nepal, and Cambodia, hypertension and central obesity prevail as major risk factors. Vietnam and Pakistan face hypertension and total cholesterol as predominant risks, while Timor-Leste sees hypertension and diabetes as prevalent. In the Lao People's Democratic Republic, total cholesterol and overweight/obesity are prominent risk factors. Sri Lanka reports hypertension and diabetes as top risk factors 12 13.

The Southeast Asian regions (SEARs) have witnessed a concerning proliferation of NCDs, marked by a pronounced surge in NCD-related fatalities between 2000 and 2012, surpassing other global regions. Currently, the region contends with an annual toll exceeding 8.5 million deaths attributable to NCDs 14. In 2021, NCDs accounted for nearly two-thirds of all deaths within countries comprising the WHO SEAR, with half of these fatalities occurring among individuals aged 30–69 years 15. Predominantly, NCD-related mortality is attributed to (CVDs), followed by cancers, chronic respiratory diseases, and diabetes. Particularly susceptible are the region's impoverished populations, predisposed to bearing the brunt of NCDs, thereby exacerbating health and socioeconomic disparities. This escalating trend is chiefly propelled by factors including urbanization, economic advancement, and globalization, precipitating the adoption of unhealthy lifestyle practices among the populace. These practices include consumption of nutritionally deficient diets, sedentary behaviors, and tobacco use, culminating in heightened susceptibility to NCDs 16.

The confluence of communicable diseases and NCDs presents a formidable obstacle for the already fragile healthcare systems and constrained health budgets prevalent in Southeast Asia 17,18. Compounded by the region's historical focus on infectious diseases and acute care, healthcare infrastructures are inadequately equipped to address the escalating demand for chronic care services 17,19. Midst of the persisting challenges in maternal and child health, coupled with the resurgence of communicable diseases, SEARs have increasingly prioritized NCDs on their public health agendas. This shift is underscored by substantial political advocacy efforts, bolstered by support from the World Health Organization (WHO) through guidance and tools like the NCD surveillance dashboard, fostering momentum and enhancing accountability in NCD management. By 2021, ten countries within the region had formulated integrated national action plans for NCDs, aligning with the Sustainable Development Goal (SDG) 3.4 target of a 33.3% reduction in premature NCD mortality by 2030, alongside the establishment of time-bound objectives addressing NCD risk factors and management 20. The NCD implementation roadmap for Southeast Asia (2022–2030) endeavors to streamline and expedite the deployment of impactful interventions, with a particular emphasis on leveraging digital solutions 21.

In response, the WHO STEPwise approach to NCD risk factor surveillance (STEPS) in 2000. This methodology is centered on acquiring fundamental data related to established risk factors that play a pivotal role in determining the major disease burden 22. The member states of the WHO have reached a consensus on 25 indicators categorized into three areas. These areas concentrate on crucial outcomes, risk factors, and the necessary national system responses for preventing and managing NCDs. This includes one target related to mortality, six targets about risk factors, and two targets associated with national systems 23. The WHO STEPS survey comprises three steps: behavioral assessment through questionnaires (STEP 1), identification of anthropometric risk factors through physical measurements (STEP 2), and identification of biochemical risk factors through measurements (STEP 3) 22.

Assessing the prevalence of NCDs and identifying high-risk populations is crucial for developing community-based interventions aimed at reducing risk factors. Currently, there is inadequate information for a comprehensive nationwide comparison of NCD prevalence and associated risk factors in the SEAR. Previous community-based studies in this area have been constrained to specific regions, providing a limited and potentially skewed representation of the overall NCD scenario 2–5,8,10,12,13,24. This study aims to assess epidemiological patterns and determinants of behavioral and biological risk factors associated with specific NCDs in SEARs. Moreover, it will help policymakers and planners SEAR take convenient and efficient steps regarding this crucial matter.

**Methods**

**Data source & study design**

We utilized data from the latest cross-sectional studies of the STEPS survey, following the standardized approach developed by the WHO for monitoring NCD risk factors in the SEAR. The STEPS survey is a global initiative conducted every three to five years in SEAR countries, employing a consistent protocol. The survey's scope encompasses all males and females aged 18 years or older **(Figure 1)**. It is noteworthy that the study considered individuals living in that country, irrespective of their citizenship status, and excluded only those temporarily visiting (e.g., tourists), residing in military bases or group quarters (e.g., dormitories), or institutionalized (e.g., hospitals, prisons, nursing homes).

Essentially, the study aimed to encompass individuals residing across all geographic areas of the country. Samples were collected using a geographically stratified probability-based method with standardized protocols across countries. STEPS surveys follow ethical and technical review processes, seeking approval from national ethics committees. Participants provide oral and written consent, ensuring the survey respects rights and safeguards ethical considerations. Informed consent is obtained from each participant before interviews, adhering to WHO guidelines 22. The characteristics of participants in the sample varied across the six countries. After the exclusion of less than 18 years participants, participants had not measured blood pressure, blood glucose, or blood cholesterol, and missing information, the weighted sample size for hypertension ranged from Maldives 1627 to 8182 in Bangladesh. For diabetes, the weighted sample size ranged from Maldives 1635 to 8185 in Bangladesh, and for hypercholesterolemia 2489 in Timor-Leste and 8185 in Bangladesh.

**Data collection**

We sourced the latest STEPS survey data for six SEARs—Bangladesh, Maldives, Myanmar, Nepal, Sri Lanka, and Timor-Leste—from https://extranet.who.int/ncdsmicrodata/index.php/catalog/. Out of 12 potential countries, we focused on these six for our study. These countries were selected based on meeting our inclusion criteria and having current standard STEPS data. Some countries were excluded either because WHO did not conduct a STEPS survey in those areas, or their data was not available in the public domain, lacked sufficient data, and relevant variables, and had unreported non-response rates. Additionally, some survey reports were either not publicly accessible or not in English.

**Selected NCD outcome variables**

We examined three categories of outcome variables: raised blood pressure (hypertension), raised blood glucose (diabetes), and raised total blood cholesterol (hypercholesterolemia). Each of these outcome variables is binary, designated as "YES = 1/NO = 0 **(Table 1)**.

Hypertension, a significant health risk factor, often shows no symptoms and is known as a "silent killer." Diagnosis requires consecutive systolic blood pressure readings≥140 mm Hg and diastolic readings≥90 mm Hg. Contributing factors include an unhealthy diet, lack of physical activity, tobacco/alcohol use, and being overweight 25. Blood pressure measurements utilized a digital monitor, with participants resting for 15 minutes. Three readings were taken, and the mean of the second and third readings was calculated. Observations outside the valid range were excluded. If the third reading was invalid, the average of the first two was considered 22. Diabetes, characterized by raised blood glucose, results from insufficient insulin production (Type 1) or ineffective use (Type 2), causing damage to vital organs. Type 2 diabetes, prevalent in those aged 35+, is linked to obesity, inactivity, and smoking, with fasting blood glucose≥126 mg/dL or 7 mmol/L indicating diabetes 26. Lifestyle changes, including regular physical activity, maintaining a healthy weight, nutritious diet, and avoiding tobacco, can prevent or delay Type 2 diabetes onset. Blood glucose levels were assessed with observations falling outside the range of fasting blood glucose <18 mg/dL or >630 mg/dL excluded 22. Raised total blood cholesterol, defined as a lipid profile ≥190 mg/dL or currently on medication, poses heart disease and stroke risks. Approximately one-third of global ischemic heart disease cases are attributed to high cholesterol. Early detection through regular screening is a key public health strategy. Observations outside the total cholesterol range of <75 mg/dL or >470 mg/dL were excluded, with none falling within this range 22.

In addition, due to insufficient measured data on blood glucose in the Maldives, this study employed self-reported blood glucose levels to assess prevalence. Participants were asked, 'Have you ever been informed by a healthcare professional that you have raised blood glucose or diabetes?' Those who responded affirmatively were categorized as diabetic patients or ‘Yes’; otherwise, responses were classified as 'No'. Furthermore, the Maldives STEP survey of 2011 did not include reporting on total blood cholesterol levels. So, we excluded that from the country-wise analysis and also in the pooled analysis.

**Selected explanatory variables**

Sociodemographic details and health measures (tobacco use, diet, physical activity) were collected. Physical assessments included height, weight, and hip/waist circumference using validated instruments, with barefoot participants in light clothing. Physical activity data was transformed into MET minutes per week. Measurements were conducted by trained enumerators and medical technologists with post-graduate qualifications. Staff underwent comprehensive training, including interactive sessions and pilot testing 22 **(Table 2)**.

**Statistical Analysis**

When analyzing survey datasets, addressing issues like uneven unit selection probabilities is crucial. Sample weights are essential to mitigate bias resulting from disproportionate sampling and non-response, significantly influencing standard error calculations. Excluding weights may lead to biased estimates. Categorical variables were appropriately defined for interpretation. After extracting variables from each country dataset, we analyzed them in two ways. Firstly, we performed a comprehensive analysis using descriptive statistics (percentages) to assess NCD prevalence among participants from different countries and socio-economic backgrounds and health measures. This stage helped us to cross-check the prevalence of each country's reports. Next, we pooled all six countries' data into a single dataset. In STATA, a singleton was introduced to handle a single primary sampling unit (PSU) within a stratum. We chose the singleton (scaled) approach for analysis. We used this method because each country has a different PSU in each study, using singleton (scaled) will provide a single PSU for all countries or combined datasets. In addition, a single PSU in the stratum can occur for various reasons such as missing data. This leads to numerous problems in analyzing the data such as not being able to calculate standard errors 27. Singleton PSUs also handle those issues and provide standard errors. Cross-tabulation and Chi-square tests evaluated the association, with significance set at p < 0.05 and 95% confidence intervals. Informed consent and adherence to ethical guidelines, including the revised declarations of Helsinki, were ensured.

Multivariable (adjusted) logistic regression analyses were then conducted to compare associated risk factors for pooled data. Results were reported as adjusted odds ratios (AOR) with their respective 95% confidence intervals and 5% level of significance. Initially, bivariable analysis (chi-square test) was performed individually for each independent variable. A significance threshold of p-value ≤ 0.05 was applied arbitrarily to determine the inclusion of covariates in the multivariable models. Additionally, we assessed multicollinearity in the final model using a cut-off value of 4.00 for the variance inflation factor (VIF) analysis 28. At this stage, all variables were incorporated into the model since the VIF values for each variable were below 4.00.

We utilized the Area under the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Receiver Operating Characteristic (AUROC) curve, sensitivity, and specificity to assess the accuracy of the best model. Higher AUROC values indicated superior model performance. In the ROC curve, a lower p-value suggests that the model effectively discriminates between two categories, with an area under the curve exceeding 0.50 29. Weighted estimates were used for national accuracy, and the STROBE Statement guided study reporting **[Supplementary Table S1]**. All analysis was conducted using STATA 16.

**Results**

All findings presented herein are based on weighted estimates to represent the population accurately. The prevalence of NCDs across different countries and cohorts remains high, underscoring the importance of preventive measures to attain the SDG 3.4 target of reducing premature NCD mortality by 33.3% by 2030.

**Country-wise description**

Summary statistics of selected parameters

The mean systolic blood pressure exhibited the highest value in the Timor-Leste at 129.85 mmHg (95% CI: 124.68-135.02) and the lowest in Maldives at 121.38 mmHg (95% CI: 120.48-122.28). Conversely, the mean systolic blood pressure for the SEAR as a whole was calculated at 126.82 mmHg (95% CI: 124.81-128.82). Similarly, the mean diastolic blood pressure was recorded as highest in the Sri Lanka and lowest in Maldives, with values of 84.46 mmHg (95% CI: 81.51-87.42) and 76.64 mmHg (95% CI: 76.00-77.27), respectively. The mean diastolic blood pressure for the SEAR was determined as 82.04 mmHg (95% CI: 80.84-83.23). Moreover, the mean blood glucose and mean total blood cholesterol levels both were observed to be highest in Bangladesh (97.32 mg/dL) and (167.64 mg/dL), respectively, while lowest in Timor-Leste (77.59 mg/dL and 139.69 mg/dL) for both parameters. Conversely, the pooled mean values for blood glucose and total blood cholesterol for the SEAR were calculated at 90.42 mg/dL and 171.66 mg/dL, respectively **(Table 3)**.

Hypertension and risk factors

As **Figure 2** shows, the percentage of participants who have hypertension was highest in Timor-Leste (39.70%) and lowest in Maldives (18.01%). **Table 7** illustrates a clear association between age and the prevalence of hypertension, with an overall increase observed as age advances. Notably, Timor-Leste and Nepal deviate from this trend. Examining the 18-29 age group, we find varying percentages of hypertension across different countries: Maldives (7.95%), Sri Lanka (9.06%), Myanmar (10.13%), Timor-Leste (46.26%), Bangladesh (8.84%), and Nepal (15.74%). In contrast, the 60 years or above age group shows higher percentages in the same countries: Maldives (60.88%), Sri Lanka (50.63%), Myanmar (45.66%), Timor-Leste (38.37%), Bangladesh (37.66%), and Nepal (44.56%). Sri Lankan (23.30%), Myanmar (27.14%) and Bangladeshi (16.82%) male exhibit the lowest percentage of hypertension, while females have the lowest percentage in Maldives (15.69%), Timor-Leste (28.03%) and Nepal (20.66%). The prevalence of hypertension is highest among individuals with no formal education to basic literacy and the lowest among people of college, university, or postgraduate completion.

Diabetes and risk factors

The percentage of participants who have diabetes was highest in Bangladesh, at 8.71%, and lowest in Timor-Leste, at 1.15% **(Figure 2)**. Analyzing the 18-29 age group, varying percentages of diabetes are observed lowest across different countries: Maldives (1.87%), Sri Lanka (1.89%), Myanmar (1.12%), Timor-Leste (0.66%), Bangladesh (4.48%), and Nepal (2.40%). In contrast, the 60 years or above age group exhibits higher percentages in the same countries: Maldives (20.49%), Sri Lanka (11.77%), Myanmar (11.49%), Timor-Leste (1.37%), Bangladesh (14.38%), and Nepal (8.00%). Accept Bangladesh and Nepal, males display the lowest percentage of diabetes, while females have the highest percentage. The other four countries exhibit the prevalence of diabetes is highest among males and lowest in females. The raised blood sugar is highest among individuals with no formal education to basic literacy in the Maldives (8.41%) and Nepal (15.97%), lowest in Sri Lanka (4.52%), Myanmar (6.03%), Timor-Leste (0.98%) and Bangladesh (8.40%) **(Table 8)**.

Hypercholesterolemia and risk factors

As of **Figure 2** the percentage of participants who hypercholesterolemia was highest in Myanmar, at 34.40%, and lowest in Nepal, at 11.13%. Analyzing the 18-29 age group, varying percentages of raised total blood cholesterol are noted across different countries: Sri Lanka (13.03%), Myanmar (18.45%), Timor-Leste (7.50%), Bangladesh (19.42%), and Nepal (6.05%). In contrast, the 60-year-old or above age group displays higher percentages in the same countries: Sri Lanka (27.21%), Myanmar (48.91%), Timor-Leste (17.46%), Bangladesh (35.73%), and Nepal (21.63%). All countries exhibit the highest percentage of raised hypercholesterolemia in females than males. Notably, except for Sri Lanka and Timor-Leste, the prevalence of hypercholesterolemia is highest among individuals with no formal education to basic literacy in other countries (**Table 9)**.

**Hypertension, Diabetes, and Hyperglycemia in SEARs**

**Table 10** presents the association between selected risk factors and major NCDs within pooled data from SEARs. In these nations, hypertension, hyperglycemia, and hypercholesterolemia have prevalence rates of 27.39%, 5.69%, and 31.21%, respectively. Among younger individuals (aged 18-29), these rates are notably lower at 10.97%, 1.35%, and 16.17%, respectively, while in the older age group (60 years and above), they peak at 46.75%, 11.35%, and 42.41%, respectively.

Females exhibit higher prevalence rates of hypertension (27.96%), hyperglycemia (6.61%), and hypercholesterolemia (35.65%) compared to males (26.84%, 4.78%, and 26.81%, respectively). Currently, married individuals display higher rates of NCDs compared to unmarried individuals. For instance, hypertension, hyperglycemia, and hypercholesterolemia rates are 29.23%, 5.86%, and 34.14% among married participants, whereas among unmarried individuals, they are lower at 24.88%, 4.30%, and 33.61%, respectively. Regarding employment status, hypertension is more prevalent among unemployed participants (27.42%) than among employed individuals, homemakers, or voluntary workers (28.47%). Similarly, hyperglycemia is more common among the unemployed, homemakers, or voluntary workers (5.84%) compared to the employed (4.86%) and unemployed (5.81%). Additionally, hypercholesterolemia rates are higher among homemakers or voluntary workers (32.36%) compared to the employed (27.90%) or unemployed (28.12%) (**Table 10)**.

The prevalence of NCDs is lowest among daily or regular smokers and highest among non-smokers or irregular smokers, although this difference is not statistically significant. Similarly, the frequency of fruit consumption per week shows no statistical significance. However, hypertension and hyperglycemia rates are highest among those who do not consume fruits weekly, while hypercholesterolemia rates are highest among weekly fruit consumers. Conversely, with vegetable consumption, the highest rates of hypertension and hyperglycemia occur among weekly consumers, while hypercholesterolemia rates are lowest among this group (**Table 10)**.

Regarding salt intake, hypertension prevalence is highest (43.41%) among those who sometimes or rarely add salt to their meals. Conversely, hyperglycemia and hypercholesterolemia rates are lowest at 2.97% and 17.32%, respectively, among those who always add salt. Similarly, the prevalence of hypertension and hyperglycemia is highest among those using coconut, groundnut, sunflower, or mustard oil, while hypercholesterolemia rates are lowest among this group and highest among those using olive, corn, or unspecified oils. In terms of physical activity, those engaged in vigorous or moderate activity show the lowest prevalence of NCDs, with rates of 20.42%, 2.53%, and 20.70%, respectively. Obese individuals demonstrate higher NCD prevalence compared to non-obese individuals, with rates of 56.39%, 11.65%, and 40.45% compared to 25.96%, 5.33%, and 30.38%, respectively (**Table 10)**.

In the adjusted model (Model 1), several factors were significantly associated with hypertension, including age, active transport, and obesity. Specifically, participants aged 18-29, 30-44, and 45-59 had a lower risk of hypertension compared to those aged 60 or above, with adjusted odds ratios (AORs) of 0.21 (95% CI: 0.13-0.31, P < 0.001), 0.43 (95% CI: 0.34-0.54, P < 0.001), and 0.78 (95% CI: 0.65-0.94, P < 0.001), respectively. Participants not engaged in active transport had 1.26 times higher odds of hypertension (AOR: 1.26, 95% CI: 1.08-1.47, P = 0.003) compared to those who were actively commuting. High-obesity participants had a 3.05 times higher risk of hypertension (AOR: 3.05, 95% CI: 2.08-4.47, P < 0.001) than non-obese participants **(Table 11).**

In Model 2, moderate activity and obesity were significantly associated with hyperglycemia. Participants not participating in moderate activity had a 4.96 times higher risk of hyperglycemia (AOR: 4.96, 95% CI: 1.53-6.11, P = 0.008) compared to those who did. High-obesity participants had a 3.89 times higher risk of hyperglycemia (AOR: 3.89, 95% CI: 1.16-8.10, P = 0.028) than those who were not obese **(Table 11).**

In Model 3, age, sex, education level, and vigorous activity were significantly associated with hypercholesterolemia. Participants aged 18-29, 30-44, and 45-59 had a lower risk of hypercholesterolemia compared to those aged 60 or above, with AORs of 0.25 (95% CI: 0.19-0.32, P < 0.001), 0.53 (95% CI: 0.46-0.62, P < 0.001), and 0.95 (95% CI: 0.83-1.09, P = 0.488), respectively. Female participants had 1.37 times higher odds of hypercholesterolemia (AOR: 1.37, 95% CI: 1.16-1.60, P < 0.001) compared to males. Additionally, participants not engaged in vigorous activity had 1.60 times higher odds of hypercholesterolemia (AOR: 1.60, 95% CI: 1.26-2.04, P < 0.001) compared to those who were vigorously active **(Table 11).**

The adjusted models demonstrated a good fit with acceptable classification accuracy, reflected in AUC values of 67.73%, 71.54%, and 65.45%, respectively for model 1, model 2, and model 3 **(Tables 12 and Figure 3).**

**Discussion**

National surveys across the SEAR have provided insights into the prevalence of hypertension and its associated risk factors. This paper synthesizes key findings from these initiatives and surveys, highlighting significant risk factors for major NCDs among Southeast Asians and emphasizing the importance of addressing behavioral factors to prevent and control this widespread health condition. Recent national surveys across the region have revealed varying rates of hypertension prevalence; for instance, 18.01% in Maldives (2011) 30, 23.77% in Sri Lanka (2014) 31, 27.93% in Myanmar (2014) 32, 39.70% in Timor-Leste (2014) 33, 20.41% in Bangladesh (2018) 34, and 26.60% in Nepal (2019) 35 and pooled prevalence is 27.39%.

In this study, significant risk factors for hypertension among Southeast Asians include age, marital status, dietary habits (such as the type of oil used and frequency of meals eaten outside), levels of physical activity (including vigorous exercise and active transport), obesity, and medication use. Additionally, some studies have highlighted statistically significant associations between hypertension and factors like sex, education level, and employment status 36–39. Consistent with our findings, previous research has indicated significant correlations between hypertension and marital status, types of oil consumed, and frequency of meals eaten outside 38–41. Besides age, behavioral factors emerge as the most crucial and modifiable risk determinants for hypertension. For instance, unhealthy dietary patterns and insufficient physical activity contribute to overweight or obesity, hypertension, and adverse lipid profiles. These behavioral factors, coupled with tobacco use, account for at least 75% of cardiovascular diseases 42. Addressing behavioral risk factors, particularly promoting healthy diets and physical activity, holds promise for hypertension prevention. Initiatives aimed at reducing salt intake can significantly contribute to hypertension prevention and control 43–46. Notably, high body mass index (BMI) stands out as a well-established risk factor for hypertension, with several studies highlighting its strong association with the condition 42,47. In 2018, India and Thailand initiated efforts to intensify their programs aimed at managing hypertension 48,49. By 2022, the India Hypertension Control Initiative had enrolled over 6 million individuals for treatment, resulting in notable enhancements in quarterly cohort blood pressure control rates 48. Thailand's initiative similarly led to the monthly diagnosis of approximately 50,000–70,000 hypertension cases, accompanied by improved blood pressure management at the clinic level 49.

The rise in noncommunicable diseases (NCDs) across the SAR is attributed to a shift in disease patterns from communicable to noncommunicable ailments 50. Factors contributing to this transition include heightened life expectancy, rapid population expansion, unplanned urbanization, low levels of literacy, and increased external debt leading to reductions in national healthcare expenditure 51. These collective issues have led to the emergence of significant regional health challenges, notably the prevalence of NCDs such as diabetes. Recent national surveys in the region have revealed varying rates of diabetes prevalence, 3.73% in Maldives (2011) 30, 6.41% in Sri Lanka (2014) 31, 5.58% in Myanmar (2014) 32, 1.15% in Timor-Leste (2014) 33, 8.71% in Bangladesh (2018) 34, 5.76% in Nepal (2019) 35 and pooled rates is 5.69%.

Within this study, several factors including age, sex, education level, marital status, dietary habits (such as extra salt intake and choice of cooking oil), levels of physical activity (including vigorous and moderate activities as well as active transport and leisure activities), obesity, and medication usage were identified as significant risk factors for diabetes among South East Asians. Additionally, some studies have highlighted associations between diabetes and socioeconomic factors such as wealth or income 52–54, although this relation is not represented in our study due to insufficient data. Consistent with existing research, our findings corroborate associations between diabetes and variables including sex 55,56, education level 57 marital status 58,59, adding extra salt, types of oil 60,61, and office-based occupation. The recent epidemic of diabetes in the region could be primarily due to environmental factors such as diet and physical activity levels coupled with a genetic predisposition 50,53,62. The recent diabetes epidemic in the region is largely attributed to environmental factors such as dietary habits and levels of physical activity, compounded by genetic predisposition. Moreover, increasing age and body weight play significant roles in diabetes susceptibility, with associations observed between diabetes and indices such as body mass index (BMI), waist-hip ratio, and abdominal obesity 62–64. These factors contribute to the heightened vulnerability to diabetes and related metabolic abnormalities among South Asians 65.

Hypercholesterolemia, characterized by elevated levels of total cholesterol in the blood, is linked to an augmented risk of cardiovascular disease 66. Its prevalence is escalating in developing nations, contributing to a global upsurge in coronary heart disease 67. Individuals with familial hypercholesterolemia (FH) face a substantially heightened risk of coronary artery disease, estimated to be ten times greater than that of healthy counterparts 68. Timely diagnosis and management of FH play a pivotal role in reducing the burden of low-density lipoprotein cholesterol (LDL-C), thereby mitigating the progression of atherosclerosis and improving coronary outcomes. Consequently, screening initiatives employing cascade testing or universal screening methods are recommended to identify FH early and mitigate cardiovascular risk in a considerable portion of the population 69. Recent national surveys in the region have revealed varying prevalence rates of hypercholesterolemia, 19.94% in Sri Lanka (2014) 31, 34.40% in Myanmar (2014) 32, 17.39% in Timor-Leste (2014) 33, 26.59% in Bangladesh (2018) 34, 11.13% in Nepal (2019) 35 and the pooled percentage is 31.21%.

This study identified age, sex, education level, work status, levels of physical activity (both vigorous and leisure), obesity, and medication usage as significant risk factors for hypercholesterolemia among Southeast Asians. However, associations observed with marital status, dietary habits, and modes of physical activity did not attain statistical significance. The positive correlation observed between age and hypercholesterolemia aligns with findings from prior studies 70,71. Similarly, the modestly increased risk of hypercholesterolemia associated with lower educational attainment is consistent with existing literature 71,72. Lifestyle and behavioral factors among the Southeast Asian population exhibit a notable influence in this study. In Thailand, transitioning towards Westernized lifestyles and behaviors poses challenges in preventing and managing coronary heart disease, along with other conditions prevalent among more sedentary and obese populations 73. In the Malaysian context, hypercholesterolemia prevalence is reported to be notably high among individuals who are overweight or obese, regardless of gender.

The studies identified several limitations, including the lack of differentiation between various categories within NCDs in Southeast Asian prevalence studies. For instance, while exploring the association with hypertension, distinctions such as primary or secondary, stage 1, or stage 2 were not considered. Similarly, diabetes data were examined in a generalized manner without distinguishing between type 1 and type 2 diabetes. Moreover, the classification of hypercholesterolemia into genetic or acquired forms was not specified. Another limitation was that all studies included in the analysis were community-based surveys, potentially underestimating the true regional burden as hospital admissions and care center data were not accounted for. Additionally, some studies relied solely on self-reported NCDs, and changes in definitions and diagnostic criteria over time may have influenced prevalence rates. However, to present prevalence data for individual countries, only the most recent studies were included, minimizing variations in diagnostic criteria as older studies were excluded.

Despite these methodological limitations, promoting public awareness through health education emerges as a crucial strategy for altering mass dietary habits and tobacco consumption behaviors in the region. Implementing initiatives such as healthy urban community design to encourage walkability and promoting healthy food options in schools and cafeterias could help mitigate the growing obesogenic environment. Tailored intervention programs targeting high-risk groups based on identified risk factors are essential for early detection and treatment of major NCDs.

In conclusion, this study identified the prevalence of major NCDs and their high-risk groups. Common health risk factors such as inadequate consumption of fruits and vegetables, tobacco use, low levels of physical activity, and abdominal obesity prevalent among adults in Southeast Asia. The study outcomes advocate for both individual and collective program interventions, with a particular focus on elderly individuals, female, and urban populations. Moreover, the findings are poised to contribute significantly to the development of comprehensive national action plans aimed at mitigating the escalating burden of NCDs. Hence, a population-based approach utilizing the primary healthcare system is warranted for risk reduction, early detection, and treatment. Given the substantial number of individuals already diagnosed with hypertension and diabetes, hospital-based strategies should also be considered. Furthermore, non-health sectors should actively participate in preventive efforts targeting specific demographic groups, considering variations in risk factor distribution across rural and urban areas, as well as by gender and socioeconomic status. In addition, a primary strategy for alleviating the burden of NCD risk factors is to prevent or reduce modifiable risk factors, which could be more cost-effective than solely providing curative services. However, addressing modifiable risk factors necessitates collaborative endeavors from multiple sectors to foster an environment conducive to behavior change. The current federal structure, wherein municipalities are responsible for various sectors including health, education, infrastructure, and environment, presents an opportunity for coordinated interventions across sectors, ultimately contributing to the reduction of NCD risk factors in Southeast Asian countries.

**Data sharing statement**

The data are available on request to the corresponding author.

**Declaration of interests**

There is no conflict of interest.

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