# HEAT-RELATED ILLNESS PREVENTION BEHAVIORS AMONG OLDER ADULTS IN SOUTHERN THAILAND: DETERMINANTS BASED ON HEALTH BELIEF MODEL

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**Abstract.** Global warming poses a major health threat, particularly through heat-related illnesses among vulnerable populations. A cross-sectional analytical study was used to analyze the determinants of heat-related illness (HRI) prevention behaviors among older adults in southern Thailand to assist effective interventions for reducing heat-related morbidity and mortality. A multistage cluster sampling was used to recruit functioning older adults ($n = 280$, Barthel ADL Index ≥12) residing in five provinces with the highest average temperatures in southern Thailand, namely Krabi, Nakhon Si Thammarat, Phuket, Songkhla, and Surat Thani. Data were collected between June and October using a structured questionnaire based on the Health Belief Model framework. Results revealed that income, perceived susceptibility, perceived severity, perceived benefits, perceived self-efficacy, and cues to action were positively correlated with HRI prevention behavior ($p$-value <0.01), whereas age and perceived barriers were negatively correlated (r = -0.13 and -0.25, respectively). Among 13 variables entered into a regression model, perceived self-efficacy, cues to action and perceived benefits were significantly associated with HRI prevention behaviors ($p$-value <0.001), explaining 47% of the variance. Cues to action emerged as the strongest predictor. These findings underscored the crucial role of psychological and motivational factors in shaping heat protection behaviors among older adults in high-temperature regions. Strengthening self-efficacy, enhancing awareness of benefits and promoting cues to action can guide the development of targeted heat illness prevention programs to protect vulnerable older adult populations from escalating heat-related health risks in southern Thailand.

**Keywords:** heat-related illness, health belief model, older adults

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## INTRODUCTION

Global warming is one of the major health threats of this century, with the World Health Organization (WHO) predicting an additional 250,000 deaths annually between 2030 and 2050 (WHO, 2023). Climate change affects human health both directly, through heatwaves, floods and storms, and indirectly through the spread of disease vectors, deteriorating air quality and food insecurity (Watts *et al*, 2015; Madani Hosseini *et al*, 2024). Older adults are considered among the most vulnerable groups due to their physiological limitations, susceptibility to chronic diseases and limited access to health services (Campbell and Keehn, 2018; Perez *et al*, 2022).

Thailand's demographic transition toward an aging society has resulted in a rapid increase in the elderly population. By 2023, older adults aged 60 years and above accounted for 20% of the population (approximately 13.2 million people) and are projected to exceed 20 million by 2040 (Department of Older Persons, 2024). At present, Thailand ranks the 9th globally on the long-term Climate Risk Index (2000-2019) and is expected to experience average summer temperatures exceeding 35 °C, with prolonged heat seasons and more frequent extreme weather events (Eckstein *et al*, 2021). In southern Thailand, which has already entered an aging society, the majority of older adults continue to work outdoors in the agricultural sector, placing them at high risk of heat stress and heatstroke (Paitoonphong, 2021; National Statistical Office, 2024).

Empirical evidence indicates that heat-related mortality rates will increase by 0.5-2.5% for every 1.5-3.0 °C rise in global temperature, with one in five heat-related deaths occurring among older adults (Chen *et al*, 2024). According to the Department of Health (2023), approximately 14,000 elderly people in Thailand will die from heat-related causes by 2080. A nationwide study of hospital admissions from January 2013 to August 2019 revealed that non-normal temperatures significantly contribute to hospitalizations in Thailand, with hot temperatures responsible for a substantial portion of all cause of admissions, particularly outpatient visits (Wen *et al*, 2024).

The southern region of Thailand has experienced accelerated warming over the past decade, with the average maximum temperature increasing 0.14 °C, and long-term trends (1979-2025) showing a rise of 0.10-0.18 °C per decade (Rodchuen *et al*, 2020; Waqas *et al*, 2025). Our study focused on five provinces experiencing the most extreme heat, namely Krabi, Nakhon Si Thammarat, Phuket, Songkhla, and Surat Thani. During the summer of 2024 (February - May), districts in these provinces, including Chawang, Hat Yai and Phrasaeng, and the municipal regions of Krabi and Phuket recorded temperatures ranging from 42.0 °C to 51.9 °C, with some areas reaching extremely dangerous conditions of 52 °C or higher, representing some of the highest temperatures recorded nationwide (The Nation, 2025; Thai PBS, 2024). These extreme thermal conditions establish these provinces as critical sites for investigating heat-related health vulnerabilities among the older adult populations.

Given this situation, our study specifically focused on heat-related illnesses (HRIs), such as heat exhaustion, heat stroke and heat stress, as the primary health threat from global warming among older adults in southern Thailand. While climate change encompasses multiple health risks, HRI represents the most immediate and quantifiable threat to this population, particularly given their continued outdoor agricultural work during increasingly severe summer temperatures. Between 2019 and 2024, Thailand recorded

212 deaths due to heatstroke, averaging 27 deaths annually. The majority of victims were men aged 41-60 years of age, often with underlying health conditions or engaging in outdoor activities during the peak heat periods (The Nation, 2025). In 2025, 32 HRI cases were reported, highlighting the ongoing risk, especially in southern provinces such as Nakhon Si Thammarat, Phuket and Songkhla, which are predicted to experience extremely high heat index values (The Nation, 2025; Office of Disease Prevention and Control Region 6, 2025).

This study investigated the determinants of HRI prevention behaviors among older adults in southern Thailand. The key risk factors investigated included living conditions, access to information and healthcare, and presence of temperature-sensitive chronic diseases, such as cardiovascular disease, diabetes and hypertension. The findings are expected to contribute to the development of effective health education programs, public health policies, and community-based interventions tailored to the specific needs of older adults, ultimately reducing heat-related morbidity and mortality among vulnerable elderly populations in tropical climate regions.

## MATERIALS AND METHODS

### Study design

The study employed a cross-sectional analytical design to investigate determinants of HRI prevention behaviors among older adults in southern Thailand. The Health Belief Model (Rosenstock *et al*, 1988) served as the theoretical framework that guided the investigation of factors associated with preventive health behaviors. The model comprises six core constructs, namely perceived susceptibility, perceived severity, perceived benefits, perceived barriers, self-efficacy, and cues to action. In addition, modifying factors, such as demographic characteristics, health status and environmental conditions, were examined as they may indirectly influence health perception and behavior.

**Study population and participants**

The study population consisted of 10,652 older adults (Department of Older Persons, 2025), who resided in five southern provinces (Krabi, Nakhon Si Thammarat, Phuket, Songkhla, and Surat Thani) with the highest average temperatures in southern Thailand (The Nation, 2025; Thai PBS, 2024).

The participants consisted of older adults residing in the five aforementioned southern provinces. The sample size was calculated using the G*power program version 3.1 (Faul *et al*, 2007) for multiple linear regression analysis, with a small effect size ($f^2 = 0.05$), $\alpha = 0.05$, power = 0.95, and 20 predictor variables including dummy variables (Cohen, 1988). The calculated sample size was then increased by 20% to account for potential participant dropout and incomplete responses. Inclusion criteria were older adults who were (i) functionally independent (Barthel ADL Index score ≥12, indicating ability to perform activities of daily living) (Jitapunkul *et al*, 1994), (ii) without dementia assessed using the Thai version of the Basic Mental Health Examination (MMSE) - Thai 2002 (Institute of Geriatric Medicine - Thai Ministry of Public Health, 2002), and (iii) without serious underlying diseases that prevent them from participating in the research project, such as cancer patients undergoing chemotherapy or with heart diseases. Exclusion criteria were older adults who were (i) with cognitive impairment preventing their ability to complete the questionnaire Thai Mini-Mental State Examination (TMSE) <17 (Train the Brain Forum Committee, 1993), (ii) currently hospitalized or in institutional care, and (iii) having severe communication impairment (hearing, speech or visual). Participants were recruited from 25 June to 20 October 2025. The final number of participants was 280.

**Sampling method**

A multistage cluster sampling method was used (Kittinorarat and Acherayawathana, 2024). Five districts from the five southern provinces with the highest temperatures were selected, with one subdistrict per district and one village per subdistrict chosen randomly. Eligible older adults were sampled from the households, one participant per household.

**Research instrument**

A structured questionnaire consisted of multiple-choice items and fill-in-the-blank responses for data collection and comprised five parts as follows.

**Part 1: Modifying factors**

This section assessed demographic, socioeconomic, health-related, and experiential characteristics, namely, age, sex, education level, marital status, current occupation, average monthly income, income adequacy, living arrangement, household size, presence of chronic disease, health insurance coverage, alcohol consumption, body mass index (BMI), and experience with HRI.

**Part 2: Health belief model perceptions**

A 30-item questionnaire was developed specifically for our study to assess five cognitive constructs based on the Health Belief Model, namely perceived susceptibility (6 items), perceived severity (6 items), perceived benefits (6 items), perceived barriers (6 items), and self-efficacy (6 items) (Rosenstock *et al*, 1988). Each item was measured on a 4-point Likert scale (from 1 = disagree to 4 = strongly agree). Negatively worded items were reverse-scored to ensure higher scores consistently reflected more health-promoting perceptions aligned with HRI prevention.

**Part 3: Cues to action**

Five items assessed stimuli that trigger HRI preventive behavior adoptions, namely healthcare provider advice, family encouragement, peer model, media exposure, and experiences (personal or vicarious heat illness experience). Items were developed through a literature review based on the Health Belief Model framework (Rosenstock *et al*, 1988). Each item was measured on a 4-point Likert scale (from 1 = never prompts action to 4 = always prompts action).

**Part 4: HRI prevention behaviors**

An HRI prevention behavior is operationally defined as a deliberate action undertaken by older adults to reduce heat exposure, maintain thermoregulation, ensure adequate hydration, and recognize early warning signs of heat-related conditions during periods of hot weather. A 20-item questionnaire was developed to assess five domains based on a comprehensive literature review (Department of Health, 2020): (i) heat exposure reduction (6 items, namely staying indoors in air-conditioned or fan-cooled buildings, using oscillating fans without direct body exposure while maintaining window ventilation, wearing wide-brimmed hats or sunglasses when outdoors, planting trees around homes for shade and temperature reduction, residing in shaded or cooler rooms, and avoiding outdoor work during hot weather periods); (ii) hydration management (5 items, namely drinking water frequently without waiting for thirst, consuming at least 8 glasses of clean water daily, monitoring urine color to assess hydration adequacy, avoiding tea, coffee, and sugar-sweetened carbonated beverages, and consulting physicians about appropriate fluid intake when chronic conditions require fluid consumption); (iii) appropriate clothing and environmental modification (2 items, namely wearing light-colored, loose-fitting, lightweight, and breathable clothing; and ensuring air conditioners and fans are functioning properly); (iv) dietary and medication management (5 items, namely avoiding greasy, excessively sweet or salty, and difficult-to-digest foods; consuming low-sugar, high-water-content fruits (*eg,* dragon fruit, orange, rose apple, and watermelon); washing hands before meals and after using toilets to prevent contracting diarrheal diseases; avoiding easily-spoiled foods, such as coconut milk-based dishes, fresh salads, and unrefrigerated cooked foods; and exercising caution with medications that may increase fluid and electrolyte loss (*eg,* antihypertensive, decongestant, diuretic, and (certain) psychiatric medication); (v) health monitoring and early warning recognition (2 items, namely monitoring daily weather forecasts, and promptly informing family members when experiencing heat-related symptoms, such as confusion, dizziness, nausea, and/or hyperventilating).

Each item was measured on a 4-point Likert scale (4 = always practice, 3 = sometimes practice, 2 = rarely practice, and 1 = never practice), with scores ranging from 20 to 80, and higher scores indicating more consistent engagement in HRI prevention behaviors.

**Validity and reliability of the instrument**

The instrument was examined for content validity by a panel of three experts: two experts in environmental health and one expert in the Health Belief Model (Rosenstock *et al*, 1988). The item-objective congruence (IOC) index values ranged from 0.67 to 1.00 (Rovinelli and Hambleton, 1977), indicating good to excellent content validity, as values ≥0.50 are considered acceptable.

The instrument was examined for reliability using a pilot study tested on 30 participants who shared similar characteristics with the target population but were not included in the main study. Internal consistency reliability was assessed using Cronbach's alpha coefficient. The overall reliability coefficient was 0.95, indicating acceptable reliability.

**Data analysis**

Descriptive statistics, namely frequencies, percentages, means, and standard deviations, were used to describe demographic characteristics. Inferential statistics, namely bivariate analyses and Pearson's correlation coefficients, were employed to examine relationships between the six Health Belief Model constructs and HRI prevention behaviors. Independent t-test and one-way ANOVA were used to compare mean differences between heat-related illness prevention behaviors among demographic variables and health-related characteristics. Multivariable analysis employing stepwise multiple regression was employed to identify significant independent predictors of HRI prevention behaviors. Variables that demonstrated significant associations (p-value <0.050) in bivariate analyses were entered as candidate predictors. The stepwise method was used to select the most parsimonious model while maximizing the explanatory variance. The assumptions of linear regression were examined following Wanichbancha (2018) and found to be satisfactorily meet (i) linearity (a linear and additive, as indicated by residual versus fitted value plots, relationships between independent (predictor) variables and dependent (outcome) variable; (ii) autocorrelation (no evidence of autocorrelation using a Durbin-Watson (DW) statistic of 1.79; (iii) multicollinearity (all variance inflation factor (VIF) values ≤4; and (iv) normality (residuals normally distributed, as evidenced by the Normal Q-Q Plot). Data were entered, coded with double-entry verification to ensure data accuracy and analyzed using Statistical Package for the Social Sciences (SPSS) version 29.0 (IBM Corp, Armonk, NY; licensed to Sirindhorn College of Public Health, Trang, Thailand, through the SIFT Analytics Group (Thailand) Co Ltd).

**Ethical consideration**

The study protocols were approved by the Human Research Ethics Committee of Sirindhorn College of Public Health, Trang, and the Faculty of Public Health and Allied Health Sciences, Praboromarajchanok Institute (Approval no. PO33/2025).

## RESULTS

The majority of the participants were female (66%), with an average age of 66 years, ranging from 60 to 94 years (Table 1). Over half (54%) had completed primary education, and 62% were married and living with their spouses. About one-third (34%) was employed in occupation related to agriculture. The average monthly income of THB14,031 was considered as sufficient by 40% of the respondents, but without

Table 1

Demographic characteristics and HRI preventive behaviors of older adult participants in five southern provinces, Thailand, 2025 (N = 280)

| Demographic characteristic | Frequency* *n* (%) | HRI preventive behavior score (mean ± SD) | Test statistic | *p*-value[†] |
|---|---|---|---|---|
| Sex | | | t = 0.26 | 0.80 |
| Male | 95 (34) | 67 ± 9 | | |
| Female | 185 (66) | 67 ± 9 | | |
| Average age in years, mean ± SD (range) | 66 ± 4 (60-94) | | | |
| Residential area | | | t = 1.69 | 0.09 |
| Urban | 122 (44) | 66 ± 8 | | |
| Rural | 158 (56) | 68 ± 10 | | |
| Education | | | F = 2.35 | 0.04 |
| Did not attend school | 24 (9) | 72 ± 7 | | |
| Primary education | 151 (54) | 67 ± 9 | | |
| Secondary education | 56 (20) | 67 ± 9 | | |
| Vocational certificate/High vocational certificate | 18 (6) | 68 ± 10 | | |
| Bachelor's degree | 25 (9) | 64 ± 10 | | |
| Higher than Bachelor's degree | 6 (2) | 73 ± 8 | | |

Table 1 (cont)

| Demographic characteristic | Frequency* $n$ (%) | HRI preventive behavior score (mean ± SD) | Test statistic | $p$-value[†] |
|---|---|---|---|---|
| Marital status | | | F = 0.54 | 0.71 |
| Single | 27 (9) | 69 ± 9 | | |
| Married and living together | 173 (62) | 67 ± 9 | | |
| Married but living separately | 8 (3) | 66 ± 10 | | |
| Widowed | 64 (23) | 66 ± 8 | | |
| Divorced | 8 (3) | 67 ± 9 | | |
| Occupation | | | F = 1.56 | 0.33 |
| Unemployed | 57 (20) | 66 ± 11 | | |
| Agriculture-related occupations | 96 (34) | 68 ± 9 | | |
| Merchant | 37 (14) | 65 ± 9 | | |
| Daily wage worker | 79 (28) | 68 ± 8 | | |
| Own business | 11 (4) | 69 ± 13 | | |
| Monthly income in THB, mean ± SD (range) | 14,031 ± 14,512 (600-50,000) | | | |

Table 1 (cont)

| Demographic characteristic | Frequency* $n$ (%) | HRI preventive behavior score (mean ± SD) | Test statistic | $p$-value† |
|---|---|---|---|---|
| Sufficiency of income‡ | | | F = 0.26 | 0.77 |
| Insufficient | 79 (29) | 67 ± 9 | | |
| Sufficient but no savings | 113 (40) | 68 ± 9 | | |
| Sufficient with savings | 88 (31) | 67 ± 9 | | |
| Number of household members, mean ± SD (range) | 3 ± 2 (1-17) | | | |
| Presence of chronic disease | | | t = 0.76 | 0.45 |
| No | 162 (58) | 68 ± 10 | | |
| Yes | 118 (42) | 67 ± 8 | | |
| Health care entitlement | | | F = 1.09 | 0.36 |
| Self-paid | 3 (1) | 64 ± 6 | | |
| State enterprise welfare | 51 (18) | 66 ± 11 | | |
| Social security | 52 (18) | 69 ± 7 | | |
| Workmen's compensation fund | 1 (1) | 76§ | | |
| Universal health coverage (UHC) | 173 (62) | 67 ± 9 | | |
| Body mass index (BMI), kg/m$^2$, mean ± SD (range) | 25 ± 5 (13-50) | | | |

Table 1 (cont)

| Demographic characteristic | Frequency* $n$ (%) | HRI preventive behavior score (mean ± SD) | Test statistic | $p$-value† |
|---|---|---|---|---|
| Alcohol consumption | | | t = 1.65 | 0.10 |
| Do not drink | 258 (92) | 68 ± 9 | | |
| Drink | 22 (8) | 64 ± 9 | | |
| Experience of HRI | | | t = 0.40 | 0.69 |
| No | 241 (86) | 67 ± 9 | | |
| Yes | 39 (14) | 67 ± 7 | | |

*Unless otherwise stated.

†Statistically significant when $p$-value <0.05.

‡Participants were asked to self-assess their income sufficiency using a three-category scale: (i) insufficient income to meet basic needs, (ii) sufficient income but unable to save, and (iii) sufficient income with ability to save; a self-reported measure reflecting participants' subjective perception of their financial adequacy.

§$n$ = 1; SD is not available.

F: F-statistic; HRI: heat-related illness; $kg/m^2$: kilogram per square meter; SD: standard deviation; *t:* *t*-statistic; THB: Thai Baht (approximately THB31 = USD1) any savings. Over half (56%) of the participants resided in rural areas, with an average household size of 3 persons. More than half (58%) reported having no chronic diseases, and 62% were covered by the Universal Health Coverage Scheme. The vast majority (92%) did not consume alcohol. Participants had an average BMI of 25 kg/m², classified as obese level 1 (Department of Health, 2025). Most (86%) participants had no experience with heat-related illnesses.

HRI prevention behaviors did not differ significantly by gender (males: mean ± standard deviation (SD) = 67.46 ± 9.33; females: mean ± SD = 67.17 ± 9.10; t = 0.26, *p*-value = 0.80), residential area (urban: mean ± SD = 66.22 ± 8.27; rural: mean ± SD = 68.08 ± 9.75; t = 1.69, *p*-value = 0.09), presence of chronic diseases (no: mean ± SD = 67.62 ± 9.79; yes: mean ± SD = 66.78 ± 8.24; t = 0.76, *p*-value = 0.45), alcohol consumption (non-drinkers: mean ± SD = 67.53 ± 9.11; drinkers: mean ± SD = 64.18 ± 9.33; t = 1.65, *p*-value = 0.10), or HRI experience (no: mean ± SD = 67.36 ± 9.44; yes: mean ± SD = 66.72 ± 7.28; t = 0.40, *p*-value = 0.69). Although not statistically significant, rural residents showed a trend toward higher prevention behaviors compared to urban residents (*p*-value = 0.09), and non-drinkers demonstrated a trend toward higher scores than alcohol drinkers (*p*-value = 0.10).

A one-way analysis of variance (ANOVA) was conducted to examine differences in HRI prevention behaviors among demographic characteristics (Table 1). Only educational level showed a statistically significant difference in preventive health behavior (F = 2.35, *p*-value = 0.04) (Table 1). No significance differences were obtained in the mean score for HRI prevention behaviors among participants who were single, married and living together, married but living separately, divorced, or widowed; who owned their own business, were merchants, daily wage workers or in agriculture-related occupation; who were with a sufficient income but no savings, an adequate income with savings, or insufficient income; and who were covered by the Workmen's Compensation Fund, with social security, with universal health coverage, or had private means.

Pearson's correlation analysis was then conducted to examine the relationships among various factors and HRI prevention behaviors of the older adult participants (Table 2). Income, perceived susceptibility, perceived severity, perceived benefits, perceived self-efficacy, and cues to action were positively correlated with preventive health behaviors related to HRI ($p$-value <0.01), with perceived self-efficacy showing the strongest correlation (r = 0.56). On the other hand, age and perceived barriers were negatively correlated with preventive health behaviors (r = -0.13 and -0.25, respectively; $p$-value = 0.01).

Stepwise multiple regression analysis was also performed to identify the variables influencing HRI prevention behaviors. Out of 13 independent variables entered into the model, three variables, namely perceived self-efficacy in preventing health impacts of HRI, cues to action and perceived benefits of preventive behaviors, were found to significantly explain the variance in HRI prevention behaviors ($p$-value <0.001) (Table 3). Together, these three factors accounted for 47% of the variance in preventive health behaviors against HRI among the participants.

To obtain the predictive HRI prevention behavior score, the following equation was used:

$$Y = 8.89 + 0.99(X1) + 1.12(X2) + 0.88(X3)$$

where Y represents HRI prevention behavior score, X1 perceived self-efficacy score, X2 represents cues to action score, and X3 perceived benefits score. The constant (8.89) was the predicted HRI prevention behavior score when all predictor variables equaled zero. The value 0.99, 1.12, and 0.88 represents the unstandardized

Table 2

Factors associated with HRI preventive behaviors among older adult participants in five southern provinces, Thailand, 2025 ($n$ = 280)

| Factors | Mean ± SD | *r* | *p*-value* |
|---|---|---|---|
| Age, years | 66 ± 4 | -0.13 | 0.05 |
| Monthly income, THB | 14,031 ± 14,512 | 0.18 | 0.01 |
| Number of household members | 3 ± 2 | 0.03 | 0.31 |
| BMI, $kg/m^2$ | 25 ± 5 | 0.05 | 0.22 |
| Perceived susceptibility score | 22 ± 3 | 0.51 | 0.01 |
| Perceived severity score | 21 ± 3 | 0.55 | 0.01 |
| Perceived benefits score | 21 ± 2 | 0.55 | 0.01 |
| Perceived barriers score | 11 ± 4 | -0.24 | 0.01 |
| Perceived self-efficacy score | 21 ± 3 | 0.56 | 0.01 |
| Cues to action score | 16 ± 3 | 0.52 | 0.01 |

Pearson's correlation coefficients ($r$) were interpreted as follows: 0.10 - 0.29 = weak correlation; 0.30 - 0.49 = moderate correlation; 0.50 - 1 = strong correlation (Cohen, 1988).

Perceived susceptibility, severity, benefits, barriers, and self-efficacy were measured using 6 items each; cues to action were measured using 5 items. All items used a 4-point Likert scale (1 = strongly disagree, 4 = strongly agree). Values reported are summed scores, with possible ranges of 6-24 for perceptions and 5-20 for cues to action. Higher scores indicate stronger perception or cue to action.

*Statistically significant when $p$-value <0.05

HRI: heat-related illness; $kg/m^2$: kilogram per square meter; SD: standard deviation; THB: Thai Baht (approximately THB31 = USD1)

Table 3

Predictors of HRI preventive behaviors using stepwise multiple regression analysis

| Independent variable | B | SE | β | *t* | *p*-value* | $R^2$ change |
|---|---|---|---|---|---|---|
| Constant | 8.89 | 3.87 | - | 2.30 | 0.020 | - |
| Perceived self-efficacy | 0.99 | 0.19 | 0.30 | 5.33 | <0.001 | 0.32 |
| Cues to action | 1.12 | 0.17 | 0.32 | 6.46 | <0.001 | 0.12 |
| Perceived benefits | 0.88 | 0.22 | 0.24 | 4.04 | <0.001 | 0.03 |
| $F = 80.71$, $R = 0.68$, $R^2 = 0.47$, $R^2adj = 0.46$, $SE = 6.72$ | | | | | | |

The model explains 47% of the variance in heat-related illness (HRI) preventive behaviors, with perceived self-efficacy contributing the largest unique variance (32%), followed by cues to action (12%) and perceived benefits (3%).

*Statistically significant when *p*-value <0.001.

B: unstandardized regression coefficient; F: F-statistic; $R^2$: coefficient of determination; $R^2$adj: adjusted $R^2$; SE: standard error; *t*: *t*-statistic; β: standardized regression coefficient

coefficient (B) for the score of perceived self-efficacy, cues to action and perceived benefits, respectively.

## DISCUSSION

### Summary of key findings

Our study was the first comprehensive investigation of HRI prevention behaviors among older adults in southern Thailand using the Health Belief Model framework (Rosenstock *et al*, 1988). We showed that three Health Belief Model constructs, namely perceived self-efficacy, cues to action and perceived benefits, collectively explained 47% of the variance in HRI prevention behaviors among older adult participants ($n$ = 280). Notably, cues to action emerged as the strongest predictor (B = 1.12, β = 0.36, $p$-value <0.001), followed by perceived self-efficacy (B = 0.99, β = 0.32, $p$-value <0.001), and then perceived benefits (B = 0.88, β = 0.27, $p$-value <0.001). Bivariate analyses revealed significant positive correlations between prevention behavior and income, perceived susceptibility and perceived severity, and of 13 independent variables, only the latter three maintained significance in the multivariable model. These findings have important implications for designing targeted interventions to protect vulnerable older populations facing intensifying heat exposure in tropical climates.

The findings of our study aligned with the Health Belief Model framework, which posits that health behaviors are influenced by individuals' beliefs about their susceptibility to health threats, the severity of these threats, the benefits of taking action, barriers to action, cue to action, and their confidence in their ability to perform protective behaviors and modify factors (Rosenstock *et al*, 1988). The strong predictive power of perceived self-efficacy, cues to action, and perceived benefits in this study confirmed the applicability of the Health Belief Model in understanding heat-related illness prevention behaviors among older adults in tropical settings (*eg*, southern Thailand).

**Cues to action as the strongest predictor of heat-protective behaviors: novel evidence from older adults in a tropical region**

Cues to action emerged as the strongest predictor with the highest coefficient (B), highlighting the importance of environmental and social prompts in triggering HRI protective behaviors among older adults in a tropical region. These cues included heat warnings from weather forecasts, advice from healthcare providers, media campaigns, or observations of health impacts of global warming among peers (Grothmann *et al*, 2017). Previous studies conducted among individuals 30-69 years of age and older adults in Western countries identified similar cues to action as significant motivators that trigger or prompt preventive behaviors against heat-related health impacts (Akompab *et al*, 2013; Valois *et al*, 2020). These cues were family encouragement for those living with others, perceived social pressure and media influence.

The significance of cues to action in our study underscored the potential effectiveness of targeted health impacts of global warming warning systems and community-based interventions in southern Thailand. These findings suggested that regular reminders and prompts on the health impacts of global warming among older adults, particularly during extreme heat events, could substantially increase the adoption of protective behaviors in this group. The importance of cues to action also aligned with other studies that demonstrated external prompts, such as health warnings related to the impact of global warming, influence the perceived effectiveness of protective measures and motivate behavioral changes (Grothmann *et al*, 2017; Kotcher *et al*, 2021).

These findings underscored the critical need for systematic, multi-channel heat-warning systems specifically designed for tropical regions, where older adults may experience heat fatigue or face the risk of heat-related mortality. Community-based interventions in southern Thailand should prioritize regular, culturally appropriate reminders delivered through trusted sources such as village health volunteers (VHVs), religious institutions and local radio broadcasts, particularly during periods of extreme heat.

**Perceived self-efficacy: a catalyst for action**

The strong predictive role of perceived self-efficacy confirmed its universal importance across diverse cultural settings and was consistent with the extensive literature identifying self-efficacy as a critical determinant of health behavior change (Bandura, 2004; Sheeran *et al*, 2016). In times of extreme heat, self-efficacy reflected older adults' confidence in their ability to implement protective measures, such as maintaining hydration, seeking cool environments, reducing outdoor activities, and engaging in information-seeking and help-seeking behaviors (Akompab *et al*, 2013).

These findings were particularly significant given the unique vulnerabilities of older adults, *viz*, physiological changes that impair thermoregulation, potential cognitive decline affecting risk perception and socioeconomic constraints limiting access to cooling resources (Kenny *et al*, 2010). Recent research demonstrated that self-efficacy often exhibits the greatest explanatory power in predicting protective actions of the older populations during health crises (*eg*, COVID-19 pandemic) (Kim and Kim, 2020). This suggested that interventions enhancing older adults' confidence in performing heat-protective behaviors may be especially effective. However, the adaptive behavior with the highest percentage reported as "never performed" is outdoor gardening during the daytime (Akompab *et al*, 2013).

The consistency of our findings in both Thai and Western settings (Akompab *et al*, 2013; Kim and Kim, 2020; Valois *et al*, 2020) indicates that building self-efficacy should be a universal priority in heat-health interventions targeting older adults, regardless of geographic or cultural context. However, the cultural manifestation of self-efficacy may differ; in the collectivist Thai society, confidence may be more strongly derived from family support and community networks than from individual autonomy, suggesting that interventions should emphasize collective efficacy alongside individual capabilities. Interventions should incorporate mastery experiences (*eg*, skills training in recognizing heat illness symptoms), vicarious learning (*eg,* peer testimonials from older adults successfully managing heat exposure) and verbal persuasion (*eg,* encouragement from healthcare providers and family members) to systematically build up self-efficacy among Thai older adults.

**Perceived benefits: understanding of advantages motivates adoption**

Perceived benefits emerged as the third significant predictor, indicating that older adults who recognize concrete advantages of protective behaviors, such as immediate relief from heat discomfort, reduced risk of heat-related illnesses and maintenance of normal daily activities despite high temperatures, are more likely to adopt these behaviors. Our findings aligned with the Health Belief Model's theoretical framework and supported previous research that demonstrated that belief in the effectiveness of protective measures significantly predicts engagement (Semenza *et al*, 2008; Akompab *et al*, 2013).

While perceived benefits showed a positive and significant effect, the predictive strength was slightly lower than that of cues to action and self-efficacy. This suggested that although understanding the advantages of protective behaviors matters, it might be less influential than having confidence to act or receiving timely behavioral cues. Additionally, some heat-protective behaviors imposed perceived costs (*eg,* avoiding outdoor agricultural activities, reducing social engagement, and increasing expenses from increased use of air conditioners) that partially offset their benefits in the older adults' decision-making processes. In the Thai context, where strong cultural norms emphasize social participation and intergenerational activities, protective behaviors that require social isolation may face particular resistance despite recognized health benefits.

Thus, health education programs should emphasize immediate, tangible benefits (*eg,* improving sleep quality and maintaining the ability to care for grandchildren) rather than abstract long-term outcomes. Programs should also address concerns regarding costs and social trade-offs by promoting practical, low-cost solutions, such as the use of natural ventilation, wearing wide-brimmed hats during outdoor agricultural activities and planting trees around homes for shade and to reduce ambient temperature.

**Variables not retained in the final model: understanding mechanisms**

While bivariate analyses revealed significant positive correlations between preventive behaviors and income, perceived susceptibility, and perceived severity, these variables did not maintain significance in the multivariable regression model. This suggested that their influence may be mediated through the three retained constructs rather than operating as independent direct predictors.

These findings were consistent with previous research that demonstrated that household income significantly predicts adaptive behaviors during heat waves, with higher-income individuals more likely to adopt protective behaviors (Akompab *et al*, 2013). This association can be attributed to the fact that individuals with higher incomes are more able to utilize air conditioning without concern for electricity costs. Previous studies have reported that the high costs of running air conditioners may act as a barrier for certain individuals to adequately adapt during heat waves (Akompab *et al*, 2013; Madrigano *et al*, 2018). However, the lack of significance of income loss in the multivariable model suggested its effect may operate indirectly, for example, by facilitating self-efficacy through resource availability or increasing exposure to health information (cues to action). These findings highlight that while addressing socioeconomic disparities remains crucial for health equity, behavior change interventions must target psychological constructs even among resource-constrained populations.

The observation of significant bivariate correlations but non-significance in multivariable analysis for perceived susceptibility and severity (threat perception) has been documented in other Health Belief Model studies. Akompab *et al* (2013) found that threat perception is not a significant predictor of adaptive behaviors during heat waves. This furthermore highlights that threat perception alone does not necessarily predict preventive behaviors. These findings may indicate that threat perception primarily influences behavior indirectly by enhancing receptivity to cues and building motivation that translates into self-efficacy (Ratwatte *et al*, 2022).

Alternatively, ceiling effects may have occurred if most participants already recognized heat as a serious threat, thereby reducing variability and predictive power. This interpretation is particularly plausible given southern Thailand's consistently high ambient temperatures and frequent media coverage of heat-related morbidity and mortality among older adults, which may have elevated baseline threat awareness in our study.

**Negative correlations: age and perceived barriers**

The negative correlation between age and heat-related illness preventive behaviors suggested that the oldest members of the older adults in our cohort might be facing unique challenges in adopting protective behaviors. This finding aligned with previous research indicating that advanced age is associated with physiological vulnerabilities, reduced mobility, and potential cognitive decline, all of which may impede the adoption of protective measures (Kenny *et al*, 2010; Fastl *et al*, 2024; Wrotek *et al*, 2025). Moreover, underestimation of vulnerabilities by the older adults may stem from past successful heat adaptation experiences, which foster a false sense of security, or from age-related alterations in thermoregulatory perception that may have impaired their awareness of heat stress (Beckmann and Hiete, 2020; Ratwatte *et al*, 2022).

A significant negative correlation between perceived barriers and preventive behaviors highlighted the importance of addressing perceived obstacles to facilitate heat-related illness protective actions among older adults. This inverse relationship parallels the findings from previous studies on preventive health behaviors, including research on COVID-19 prevention, that reported similar negative correlation, thereby reinforcing the notion that reducing perceived barriers constitutes a viable strategy for enhancing protective behavior adoption (Kim and Kim, 2020; Karimy *et al*, 2021). In the context of heat-related illness, older adults who perceive fewer barriers, such as the lack of access to cooling resources or social support, are more likely to adopt preventive measures like staying hydrated and avoiding outdoor activities during peak hot periods (Hansen *et al*, 2011; Doherty *et al*, 2025). Effective interventions aimed at reducing perceived barriers include community education on the risks of heat exposure, improving access to cooling centers and enhancing social support networks for older adults. These strategies can help mitigate the risks associated with extreme heat and promote healthier behaviors during these conditions (Doherty *et al*, 2025; Johar *et al*, 2025).

**Primacy of psychological factors over demographic characteristics**

Contrary to Western studies documenting higher health-protective behaviors in women (Moran and Del Valle, 2016), we found no significant gender differences in HRI prevention practices among older adults in southern Thailand, an observation likely attributable to equivalent occupational heat exposure to both men and women in an agricultural setting (Tantipanjaporn *et al*, 2025). When environmental threats are uniformly experienced across sexes, behavioral disparities diminish as both groups develop comparable adaptive responses.

Chronic conditions can exacerbate during heat waves, precipitating life-threatening complications such as heat exhaustion or heat stroke (WHO, 2024). However, we found that the presence of chronic disease did not significantly predict HRI preventive behaviors, suggesting inadequate health education of those most physiologically vulnerable to heat-related morbidity.

Our observation of the absence of association between prior heat-related illness and HRI preventive behaviors challenged the Health Belief Model's assumption that direct health threats automatically enhance perceived susceptibility. This disconnect suggested that adverse health events, without subsequent health education or counseling, failed to establish a lasting imprint necessary for sustained behavior modification (Matthews *et al*, 2024). From the Health Belief Model's perspective, experience must be cognitively processed and explicitly linked to preventive actions through guided interventions rather than assumed to automatically cause behavioral changes (Alyafei and Easton-Carr, 2025).

Rural residence showed a marginally non-significant trend toward higher HRI preventive behaviors, suggesting a greater occupational heat exposure and limited cooling infrastructure in rural areas (Kovach *et al*, 2015; Jagai *et al*, 2017). However, this association warrants cautious interpretation and further investigation with a larger cohort.

Alcohol abstainers also showed a marginally non-significant trend toward higher HRI preventive behaviors. While this finding did not reach statistical significance, it was concordant with physiological evidence of alcohol consumption impairing thermoregulation and exacerbating dehydration through a diuretic mechanism, thereby elevating vulnerability to HRI (Morris *et al*, 2024). However, this association requires confirmation in future studies using larger cohorts before recommending any targeted intervention.

**Significant contribution to knowledge: the first study in Thai older adults**

To the best of our knowledge, our study is the first to systematically examine HRI prevention behaviors among older adults in Thailand using a theoretical framework. Our research made the following contributions.

(1) The critical role of cues to action highlighted the need for comprehensive extreme heat warning systems delivered through accessible channels, including family caregivers, village health volunteers, local media, and social support networks. The strong influence of perceived self-efficacy suggests interventions should prioritize skill-based training, behavioral modeling and social reinforcement, in parallel with a clear demonstration of the effectiveness of preventive actions in mitigating heat-related health risks.

(2) The disparities in coping with heat-related problems in the more senior older adults and those in the low socioeconomic groups necessitate a targeted intervention policy, such as financial assistance for home improvements and community-based support systems to overcome practical barriers.

(3) As Thailand confronts more frequent extreme climate changes, for example, higher seasonal temperatures, we have provided quantitative evidence for the necessity of public health strategies to protect vulnerable older populations from HRI. The identification of low-cost, scalable interventions, particularly strengthening early warning systems through existing local communication networks, offers feasible pathways for resource-limited tropical regions.

**Study limitations**

Our study contained several limitations. Firstly, the cross-sectional design precluded causal inference; longitudinal studies will be needed to establish temporal relationships among Health Belief Model constructs and the observed behaviors. Secondly, the use of a self-reported questionnaire may be subject to bias towards appeasing replies; future research should incorporate objective measures, such as hydration biomarkers and environmental monitors. Thirdly, we focused our study on five southern provinces with the highest temperatures, thereby limiting the generalization of the results to other regions of the country with their different climate patterns and socioeconomic characteristics. Multi-region studies are warranted to examine the effects of geographic variations on the study results. Fourthly, the use of convenience sampling and exclusion of cognitively impaired older adults may have introduced a selection bias, potentially overrepresenting perceptive participants. Fifthly, the 53% unexplained variance indicated the existence of important unmeasured determinants, viz, social support, cultural beliefs, housing quality, and health literacy. And lastly, this study did not assess actual heat exposure or HRI outcomes; future research should link behaviors with objective health outcomes to demonstrate the clinical relevance.

**Implications for future research**

These findings reveal several important opportunities for the following investigations: (i) longitudinal studies to examine temporal relationships among Health Belief Model constructs, establish causal pathways and identify the relationship between perceptions and behavior change in the hot seasons, thereby revealing critical windows of opportunities for applying cues to action; (ii) randomized controlled trials to test theory-driven interventions, such as multi-channel cue-to-action systems integrating SMS alerts, community announcements and village health volunteer visits; programs of self-efficacy using peer models and skills training; and benefit-enhancement interventions demonstrating the tangible advantages of protective behaviors; and (iii) qualitative research to explore cultural beliefs influencing heat-protective behaviors, such as Buddhist concepts of accepting suffering and perceptions of heat as a natural phenomenon versus a health threat, thereby leading to the understanding of cultural frameworks that could assist in formulating culturally tailored interventions and explaining the variance observed in protective behaviors.

**Concluding remarks**

Our study provided the first empirical evidence of the determinants of HRI prevention behaviors among older adults in southern Thailand, demonstrating that cues to action, perceived self-efficacy and perceived benefits were critical intervention targets for protecting vulnerable populations facing climate change-related heat exposure. The findings underscored the need for systematic, culturally appropriate alert systems and confidence-building interventions that extend beyond traditional knowledge-focused approaches, while also highlighting the importance of addressing structural barriers and socioeconomic disparities that impede protective actions among the most vulnerable older adults.

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## CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

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