Article

Journal of Health Management
1–11

DOI: 10.1177/09720634261466388
journals.sagepub.com/home/jhm
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Exploring the Relationship Between Individuals' Coping Measures and the Economic Burden of Heat-related Illnesses: Insights from Central Vietnam

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Abstract

Heat-related stress has emerged as a pressing public health concern worldwide with significant socio-economic implications. This study focused on Vietnam, a tropical country that is highly vulnerable to extreme heat events, to investigate the interplay between individuals' coping measures and the economic burden associated with heat-related illnesses. Employing a two-stage estimation approach, we identified influential factors that shape individuals' choices regarding coping measures and estimated the treatment effect associated with these decisions. Our findings highlight the significance of background diseases, heat exposure in working conditions, perceived effectiveness of available coping measures, gender and educational attainment of household heads as key determinants of the adoption of coping measures. Furthermore, we demonstrated that pre-existing health conditions, age and a longer duration of exposure influence the economic burden of heat-related illnesses. The results reveal that the effective implementation of both individual and combined coping measures substantially reduces this burden, with multiple measures exhibiting a greater impact than single measures alone. These findings offer valuable insights into policymakers and healthcare providers, enabling them to develop interventions that promote the adoption of coping measures and mitigate the economic consequences of heat-related stress.

Keywords

Adoption decisions, coping measures, economic burden, heat-related illness, Vietnam

Introduction

Extreme heat events are a growing global concern, including in Vietnam, with profound socio-economic implications (Ebi et al., 2021; Keith et al., 2019; Kien et al., 2023; Meehl & Tebaldi, 2004; Nguyen et al., 2023; Yang et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) (2018) highlighted the increasing frequency and severity of heatwaves, projecting their continued escalation in the coming decades. Heatwaves can have various detrimental health effects, such as heat stroke, heat exhaustion, dehydration and cardiovascular disorders (Liu et al., 2022; Luber & McGeehin, 2008). Consequently, the economic burden associated with extreme heat exposure is substantial, including medical expenses, decreased productivity and compromised quality of life (Centers for Disease Control and Prevention, 2021). The World Health Organization reported a 54% increase in heat-related deaths between 2000 and 2016, with an estimated 157,000 deaths attributed to heat stress in 2018 alone (WHO, 2019). Quiggin et al. (2021) estimated that approximately 1.1 billion people worldwide, including 44 million in the labour force, are vulnerable to extreme heat events. In Vietnam, cold and heat waves accounted for approximately 1.42% of all deaths between 2003 and 2017 (Nguyen et al., 2023). The impact of heat-related stress in Vietnam extends beyond its direct health effects and has significant economic consequences (Kjellstrom et al., 2019).

In order to effectively address the negative impacts of heat-related stress, individuals can adopt various coping measures (Turek-Hankins et al., 2021). A number of studies have examined factors that influence the adoption of coping measures for heat-related stress (Luber & McGeehin, 2008). Although certain coping measures, such as using fans or air conditioning, have been found to effectively reduce the risk of heat-related illnesses (Luber & McGeehin, 2008), the effectiveness of other measures, such as drinking water or

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wearing protective clothing, remains inconclusive (Turek-Hankins et al., 2021). Furthermore, the economic burden associated with heatwaves has also been extensively investigated, highlighting the significant costs of heat-related illnesses (Kansra, 2018). These findings underscore the urgent need for effective adaptation and mitigation measures to minimise the economic consequences of heatwaves.

However, there is a gap in our understanding of how these two issues—the coping measures adopted by individuals and their impacts on the economic burdens associated with heat illness—are interrelated (Turek-Hankins et al., 2021). Moreover, the effectiveness of coping measures in mitigating the adverse effects of heatwaves remains poorly understood in the existing literature. Therefore, further research is needed to explore the interplay between the adoption of coping measures and the economic burden of heat-related illnesses, since the effectiveness of coping measures may vary depending on several factors such as individual's characteristics, socio-economic status and geographic location. Moreover, it is crucial to investigate how the level of adoption influences the effectiveness of coping measures in reducing the economic burden. It is possible that certain coping measures will only be effective when implemented on a specific scale, whether individually or as a comprehensive package.

This study contributes to the existing literature by investigating the relationship between coping measures and the economic burden of heat-related stress in Central Vietnam. We employed a two-stage estimation approach to examine the factors influencing individuals' adoption of coping measures and their effectiveness in reducing the economic burden. To estimate the economic burden, we adopted the cost-of-illness (COI) approach, which is commonly used to assess the economic impact of diseases. However, previous studies have typically neglected the effectiveness of coping measures in reducing overall economic burden studies (Aung et al., 2022; WHO, 2019). Further, several statistical methods have been employed to assess the adoption of coping measures, including probit, logit, multinomial logit and two-stage estimation. The two-stage estimation method, widely used across various fields, first estimates the adoption choice and then the treatment effects, addressing endogeneity and enhancing validity (Greene, 2000; Heckman, 1979). Thus, we used a two-stage estimation to examine how coping measures affect the economic burden of heat-related illness, overcoming the limitations of methods that do not consider the effectiveness of these measures. This study is among the few that link the adoption of coping strategies to heatwave outcomes using a two-stage approach.

Materials and Methods

Data

This study employed a stratified quota sampling method that considered the level of exposure to heat-related stress, location and socio-economic factors such as age, gender, education and income in four selected study sites. Heat-related illnesses, including heat cramps, heat and sunstroke, oedema due to heat, heat exhaustion and fainting due to heat, were found to be closely related to exposure to high temperatures. The study was conducted in Central Vietnam, specifically in the provinces of Quang Binh, Thua Thien Hue, Binh Dinh and Khanh Hoa (Figure 1).

The study involved interviews with 400 randomly selected patients from a list of patients at central hospitals in 2022. Due to missing information on the coping measures applied by individuals, only 394 valid observations were used for further analysis. To be eligible for participation, individuals had to meet specific recruitment criteria. This included having knowledge, exposure or experience related to the specific heat-related illness under investigation. Additionally, participants were required to be 18 years of age or older. Prior to participating in the survey, all participants provided informed consent, ensuring their voluntary involvement in the study.

Empirical Model

Expected Utility Theory (EUT) is a decision-making framework that is widely used to analyse choices under uncertainty. According to the EUT, individuals select options that maximise their expected utility. In the context of heat-related stress, EUT suggests that individuals choose coping measures that maximise their expected utility by reducing the negative impacts of heat exposure, such as heat stroke or dehydration. Thus, we adopted EUT as a theoretical framework to analyse the selection of coping measures for heat-related stress in this study.

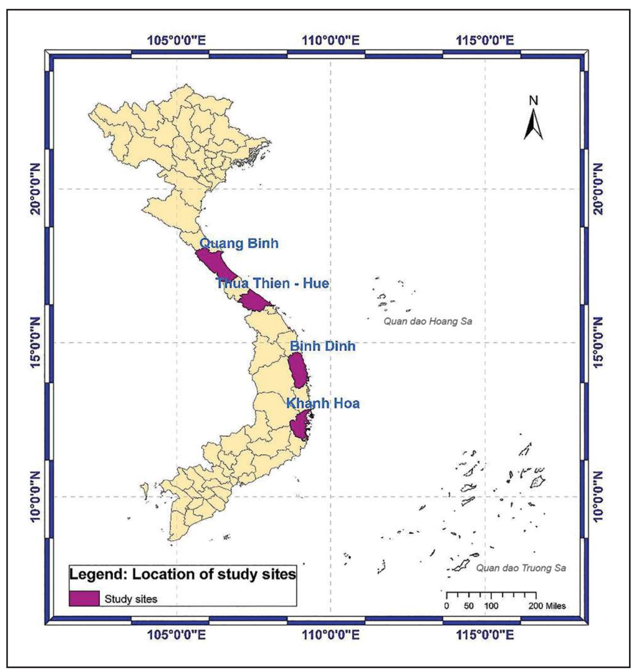

Figure 1. Map of the Study Sites.

To investigate the adoption of coping measures and their impact on the cost of heat-related illness, this study used a two-stage estimation approach. In the first stage, factors influencing individuals' decision to adopt coping measures were examined, including individual characteristics and contextual factors (McFadden, 1974). The second stage focused on estimating the treatment effect of coping measures, specifically their impact on the economic burden of heat-related illnesses.

Stage 1: Choice of Coping Measures to Heat-related Stress

The first stage of the model aims to analyse the factors that influence individuals' selection of coping measures in response to heat-related stress. The respondents in this study were presented with various combinations of coping measures, which were identified through stakeholder consultations. These measures included the use of air conditioning, fans, tree planting, staying indoors, taking multiple showers per day, wearing thin clothing, working in the early morning or late afternoon, swimming and upgrading their house. The respondents were asked to select one or more measures, which were then classified into three groups: non-adoption (j = 1), adoption of a single measure (j = 2) and joint adoption of multiple measures (j = 3). Typically, limited attention has been paid to the classification of coping measures based on the number of groups of measures adopted. This classification can provide a more nuanced understanding of how individuals respond to heat-related stress and can inform the design of effective interventions to promote the adoption of coping measures, either individually or as a package. The model we use in Stage 1 is called the latent model $(Y_{ji}^{*} = X'\beta + \varepsilon)$, which implies that when a participant chooses one option among several options, it is considered to have a higher utility than other options, as indicated by:

$$Y = \begin{cases} 1 \text{ if } Y_{ji}^{*} > \text{or } \tau_{1i} < 0 \ldots \\ J \text{ if } Y_{ji}^{*} > \text{or } \tau_{ji} < 0 \end{cases} \quad \text{for all } m \neq j \qquad (1)$$

Let Y^* be the latent response function of the observed choices of coping measures (Y) adopted by individuals in response to heat-related stress. X is the matrix of explanatory variables. Equation (1) states that the ith individual will choose j over any other combination m if it provides greater expected utility than any other combinations, that is, if $\tau_{ji} = m \neq j$, $\max(Y_{mi}^{*} - Y_{ji}^{*}) < 0$. The model can be estimated using multinomial logistic regression. The two-stage estimation process is connected by utilising the inverse Mills ratios (IMR), $\widehat{\text{IMR}} = \phi\left(FX'\beta\right)\big/\Phi\left(F\left(X'\beta\right)\right)$, where ϕ is the probability density function, Φ is the cumulative distribution function, obtained from Stage 1 to Stage 2. This helps us to take into consideration any correlation between the residuals of the two stages, which in turn leads to unbiased estimation. To estimate the parameters for Stage 1 and Stage 2, we use the STATA function mlogit and the user-written command selmlog (Bourguignon et al., 2002).

Stage 2: Impact on the Economic Burden of Disease

The second stage of the model aims to estimate the impact of the coping measures on the cost of illness associated with heat-related stress. The model was estimated using a linear regression approach, with the dependent variable representing the total cost of illness, COI (e.g., medical expenses, lost productivity) and the independent variable representing the coping measures adopted by individuals. The model can be specified as follows:

$$\left\{ \begin{array}{ll} \text{Regime } 1: \text{COI}_{1i} = Z_{1i}' \beta_1 + \widehat{\text{IMR}}_{ji}\gamma_1 + \varepsilon_{1i} & \text{if } Y = 1 \\ \text{Regime } j: \text{COI}_{ji} = Z_{ji}' \beta_j + \widehat{\text{IMR}}_{ji}\gamma_j + \varepsilon_{ji} & \text{if } Y = j \end{array} \right\} = 2,3 \qquad (2)$$

where COI_{ji} is the outcome variable of the ith respondent in combination (j). The cost of illness is the dependent variable representing the cost of illness associated with heat-related stress for three combinations. Z is the vector of independent variables and ε represents the error term.

Selecting explanatory variables is crucial in identifying factors behind individuals' choice of coping measures and estimating the economic burden of heat stress. Based on the literature review, key factors include individual characteristics like age, gender, education, household size, income and knowledge of heat-related illnesses. Exposure to heat risks, pre-existing conditions and personal experience with heat-related symptoms also influence health outcomes. Perceived risks, access to information and socio-economic factors such as income and education further shape coping strategies. Additionally, the cost of illness is influenced by exposure, health conditions, socio-economic status, occupation and the effectiveness of prevention measures (Agyekum et al., 2022; Aung et al., 2022; Himmler et al., 2020; Sahay, 2019; Turek-Hankins et al., 2021; Zhang et al., 2016). Understanding these factors is vital for mitigating the economic impact of heat-related illnesses.

Estimation of Treatment Effects

The two-stage estimation approach enables us to estimate the impact of implementing coping measures as a treatment effect (Heckman, 1979). The average effect of treatment on the treated (ATT) is a statistical measure used to estimate the impact of a treatment or intervention on those who actually receive it. It is calculated as the difference in outcome between the treated group and a comparison group, divided by the number of individuals who received treatment. The ATT is defined as the difference between Equations (3) and (4):

Adopters with adoption (actual)

$$E\left(\text{COI}_{ji} \mid Y = j, Z, \widehat{\text{IMR}}\right) = Z_{ji}' \beta_j + \widehat{\text{IMR}}_{ji}\gamma_j + \varepsilon_{ji} \qquad (3)$$

Adopters had decided not to adopt (counterfactual)

$$E(\text{COI}_{1i} \mid Y = 1, Z, \widehat{\text{IMR}}) = Z_{1i}' \beta_1 + \widehat{\text{IMR}}_{ji}\gamma_1 + \varepsilon_{1i} \qquad (4)$$

We calculated ATT by subtracting the expected values of the outcomes of interest for adopters and non-adopters in actual and counterfactual scenarios, as follows:

$$\begin{aligned} \mathrm{ATT} &= E\left(Y=j, Z, \widehat{\mathrm{IMR}}\right) - E\left(Y=1, Z, \widehat{\mathrm{IMR}}\right) \\ &= Z\left(\beta_j - \beta_1\right) + \widehat{\mathrm{IMR}}_{ji}\left(\gamma_j - \gamma_1\right) \end{aligned} \tag{5}$$

We also calculated the unconditional average treatment effect (UATE) for comparison purposes. The difference between the ATT and UATE is that the ATT estimates the effect of the treatment for those who actually received it, while the UATE estimates the effect of the treatment for the whole population, including those who did not receive it (Austin, 2014).

Non-parametric Analysis

We initially employed non-parametric analysis, a statistical method that does not rely on assumptions about data distribution (Krzywinski & Altman, 2014). Non-parametric analysis is useful for comparing the effectiveness of coping measures without making distribution assumptions. In our study, we used non-parametric analysis to provide an initial assessment of how adopting coping measures impacts the cost of heat-related diseases. Subsequently, we employed a two-stage estimation approach to gain a deeper understanding of coping measures adoption and its impact on respondents.

Empirical Results and Discussions

Descriptive Analysis

Table 1 presents descriptive statistics for the variables used in the study. In Stage 1, the dependent variable is the adoption of coping measures, categorised as non-adoption (j = 1), adoption of a single measure (j = 2) or joint adoption of multiple measures (j = 3). The average adoption rate is 0.902, indicating widespread adoption of coping measures. In Stage 2, the cost of illness represents the economic burden of heat-related illnesses, measured in millions VND per year. The average cost of illness is 29.85 million VND ($1,297.8), with a relatively large standard deviation of 38.25 million VND ($1,663.0), suggesting a wide range of costs among participants.

The study examined several independent variables associated with heat-related stress, including individuals' background diseases, the length of hospital stay due to heat-related illnesses, personal experience with symptoms of heat-related illnesses (Table A1), and the extent of exposure to heat stress in working conditions (Table A2). Perceived individual anxiety and risks associated with heat-related illness, prediction of future risks associated with heat-related illness and perceived effectiveness of coping measures were also considered. On average, the number of background diseases per respondent was 1.29. The mean length of hospital stay due to heat-related illnesses was 17.36 days per year, with the

Table 1. Descriptive Statistics of Key Variables.

Variables	Description	Mean	SD	Min.	Max.
Dependent Variables					
Combinations of coping measures	Non-adoption (j = 1), adoption of a single measure (j = 2) and joint adoption of multiple measures (j = 3)	1.39	0.89	0	2
Cost of illness	Total economic burden related to heat illnesses (*million VND*)	29.85	38.25	2.4	287.6
Individual Relationship with Heat Risks					
Background diseases	Number of background diseases (heart disease, respiratory disease, high blood pressure and so forth) (*number*)	1.29	0.74	0	4
Length of stay	Number of days enrolled in hospitals (*days/year*)	17.36	15.94	2	113
Personal experience with heat-related illnesses (symptom)	Number of symptoms due to heat stress (*number*)	2.11	0.75	1	3
Exposure to heat at work	Extent of exposing to the heat stress (*1–5 from rarely to very often*)	2.48	0.92	1	5
Perceived Risk/Uncertainties Associated with Heat-related Illnesses					
Perceived individual anxiety	Perception of individual anxiety about the effects of heat stress (*1 = yes*)	0.075	0.263	0	1
Perceived individual risks	Level of perceived individual risks caused by the extreme heat to health (*scaled 1–5 from strongly disagree to strongly agree*)	3.91	0.76	1	5
Prediction of future risks associated with heat-related illness	Level of predictions on the probability of prolonged/severe/peak heat (*1 = likely*)	0.766	0.423	0	1
Perceived effectiveness	Perceived effectiveness of coping measures available (*1 = effective*)	0.012	0.111	0	1

(Table 1 continued)

(Table 1 continued)

Variables	Description	Mean	SD	Min.	Max.
Individual Characteristics					
Knowledge	Knowledge assessment of individuals on the impact of heat stress (*number of right answers*)	2.45	1.25	0	4
Age	Age of the respondent (*years*)	65.54	14.93	18	97
Gender	Gender of the respondents (*1 = female*)	0.452	0.498	0	1
Education	Levels of education (*scaled 1–5 from primary school and lower to university and higher*)	2.61	1.34	1	5
Household size	Number of persons living in the family (*persons*)	4.98	2.42	1	19
Household income	Annual household income (*scaled 1–5 from low to high*)	3.30	1.14	1	5
Access to Information on Heat Stress					
Warning	Access to heat warning information *(1 = yes)*	0.575	0.494	0	1
Warning intensity	Level of warning information received (*1–5 from rarely to very often*)	2.37	0.76	1	5
Information source – TV	Access to heat information from TV (*1 = yes*)	0.345	0.475	0	1
Information source – Authorities	Access to heat information from Authorities (*1 = yes*)	0.152	0.359	0	1
Information source – Social media	Access to heat information from Social media (*1 = yes*)	0.197	0.398	0	1

Note: VND, Vietnamese Dong (approximately 23,000 VND/$ as of 2022).

number of symptoms due to heat stress being 2.11. The mean extent of exposure to heat stress in working conditions was 2.48, with a standard deviation of 0.92.

The study also investigated individual characteristics such as age, gender, education, household size and access to health information, and found that the mean knowledge assessment score is 2.45, indicating a moderate level of knowledge among respondents regarding the impact of heat stress. The mean age of the respondents is 65.54 years, and the mean year of attending school is 2.64 years. The majority of respondents are male, and the mean household size is almost five persons.

To effectively address the negative consequences of heat-related stress, individuals have various coping measures at their disposal, including technological, social and behavioural strategies (Turek-Hankins et al., 2021). This study identified the coping measures individuals employ to tackle challenges related to heat risks (Table A3). Moreover, it is crucial to explore how the effectiveness of coping measures in reducing the economic burden of heat-related illnesses varies based on their level of adoption. Certain coping measures may only be effective when implemented individually or as a comprehensive package. Therefore, this study focused on comparing the treatment effects associated with different levels of coping measures adopted (Table 2). Among the participants, 27.91% (n = 110) indicates that they did not employ any specific coping measures to tackle heatwaves. On the other hand, 5.32% (n = 21) reported the adoption of a single measure (j = 2) as their coping strategy to mitigate the impact of heatwaves. The majority of participants, accounting for 67.51% (n = 266), opted for the joint adoption of multiple measures (j = 3) to address heatwaves. These individuals employed a combination of different coping measures to enhance their resilience and mitigate the effects of heatwaves.

Results of Non-parametric Analysis

This section provides visual comparisons of the likely impacts of different coping measures adopted by respondents in response to heat stress, using kernel density estimation. Comparing the impact outcomes (COI) among different combinations, we found that the unconditional distributions of adoption (j = 1 and j = 2) are likely to be concentrated on the far left, indicating the presence of positive impacts of adoption in reducing COI over non-adoption (Figure 2), as expected. This would be the first sign to express the impact of the adopted coping measures; however, more rigorous analyses are needed to further confirm this evidence.

Results of Two-stage Estimation on the Choice and Impacts of Coping Measures

Factors Affecting the Choice of Coping Measures

The first-stage model determined the factors that influence the choice of coping measures adopted by people to deal with heat-related stress (Table 3). A positive parameter indicates that the relative likelihood of adopting a measure increases with the likelihood of non-adoption. Overall, our findings confirm that factors such as background diseases, exposure to heat in working conditions, perceived effectiveness of

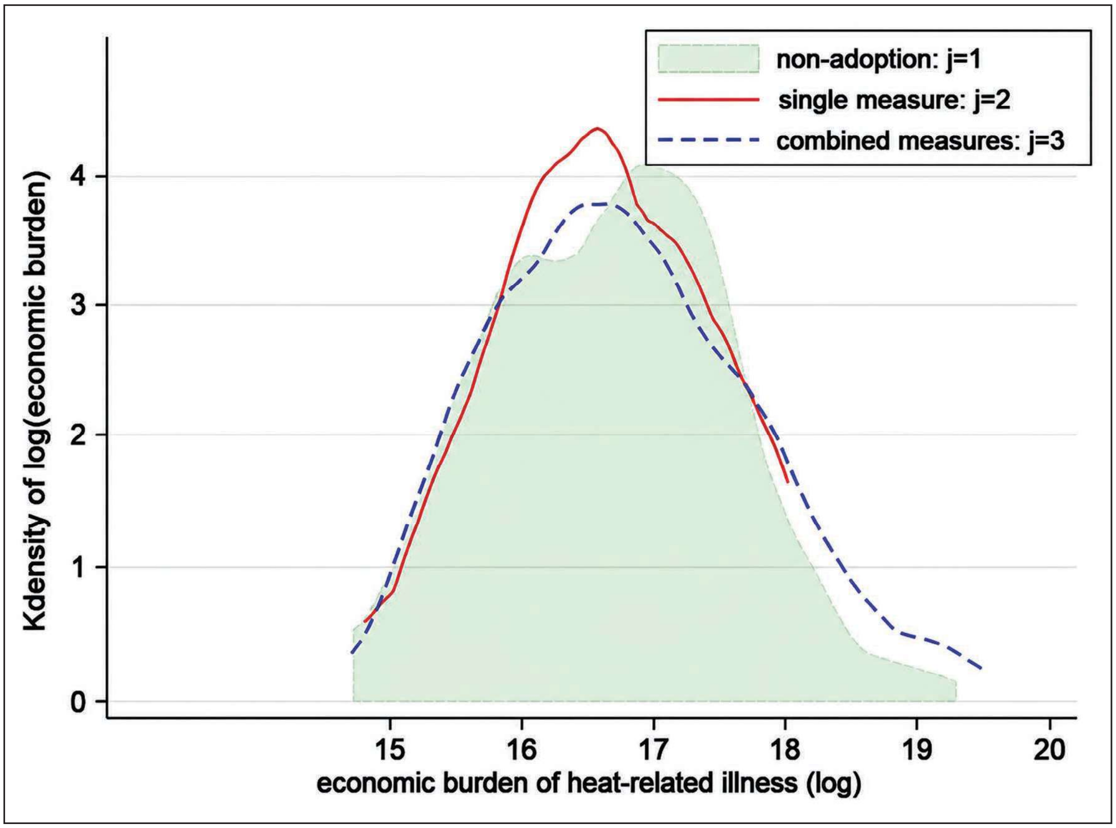

Figure 2. Unconditional Kernel Density Distributions – Log(Cost of Illness – COI).

Table 2. Combinations of Adoption of Coping Measures to Tackle Heatwaves.

Choice	Combinations of Coping Measures	Frequency	% Yes	Cumulative
1	Non-adoption (*j* = 1)	110	27.91	27.91
2	Adoption of a single measure (*j* = 2)	21	5.32	33.24
3	Joint adoption of multiple measures (*j* = 3)	266	67.51	100.00

Table 3. Factors Affecting the Choice of Coping Measures.

	Adoption of a Single Measure (*j* = 2)		Adoption of Combined Measures (*j* = 3)	
Measure	Coef.	SE	Coef.	SE
Background diseases	0.184*	0.110	0.156*	0.100
Personal experience with heat-related illnesses	−0.300	0.536	−0.16**	0.081
Exposure to heat in working condition	0.489***	0.002	0.401***	0.186
Perceived individual anxiety	−0.323***	0.024	−0.153	0.823
Perceived individual risks	−0.220	0.224	−0.066	0.149
Prediction of future risks associated with heat-related illness	0.067	1.337	0.895	0.605
Perceived effectiveness	0.333*	0.224	0.252***	0.083
Knowledge	0.065	0.094	0.155***	0.050
Age	−0.01	0.038	−0.017*	0.010
Gender	−0.904***	0.232	−0.271**	0.108

(Table 3 continued)

(Table 3 continued)

Measure	Adoption of a Single Measure (j = 2) Coef.	SE	Adoption of Combined Measures (j = 3) Coef.	SE
Education	0.39*	0.203	0.331**	0.132
Household size	0.153	0.243	0.098***	0.008
Household income	−0.295	0.496	0.053*	0.031
Warning	1.255*	0.698	−0.031	0.264
Warning intensity	−0.353	0.718	0.392	0.258
Information source – TV	−0.446	0.464	0.119	0.019
Information source – Authorities	−1.228	0.743	0.269	0.754
Information source – Social media	2.044***	0.783	0.313***	0.105
Constant	−0.562	3.319	1.197	1.260

Notes: Base-outcome is non-adoption (j = 1); *, **, *** Significant at 10%, 5% and 1%, respectively. SE: Standard error.

available coping measures, gender of household head, education level of household head, and access to social media information are the main drivers of adopting coping measures in response to heat-related stress.

More specifically, the findings revealed that individuals with background diseases and higher exposure to heat in their working conditions were more likely to adopt both single and combined coping measures. This suggests that individuals who have pre-existing health conditions and experience greater heat stress at their workplace are more inclined to take proactive measures to cope with heat-related challenges. In addition, people who are exposed to heat in their work conditions are more likely to adopt single and combined coping strategies, to mitigate the adverse impacts associated with heat stress. The findings are consistent with the literature that has found that occupational factors, such as physical and work conditions, can impact health-related behaviour (Laaksonen et al., 2009). The results highlight the importance of targeting interventions and support towards these vulnerable groups to enhance their resilience to heat-related stress. Moreover, for individuals' perceived effectiveness of available coping measures individuals who perceive a higher level of effectiveness in the available coping measures are more likely to adopt those measures individually or simultaneously. Regarding household income, higher household income is statistically significantly associated with the adoption of combined coping measures. This finding is consistent with previous studies that have established a positive relationship between income and health-related behaviours, including the adoption of coping measures (Sahay, 2019; Turek-Hankins et al., 2021). The positive association between income and combined coping measures suggests that individuals with higher income have greater resources to adopt multiple coping measures concurrently (Berman et al., 2015). Individuals with higher education levels often possess a better understanding of the available coping strategies and their effectiveness, allowing them to make informed decisions when faced with extreme heat events.

However, the findings from our study suggest that access to information, including heat warning messages and information sources (excluding social media), did not have a significant influence on the choice of coping measures for individuals; it is indeed a surprising result. It contrasts with previous studies indicating the importance of information in decision-making related to coping with extreme heat events. This may be the case that the existing information sharing systems in Vietnam lack provisions for heat-related risks and for targeted-vulnerable groups, emphasising the need for a dedicated system to enhance preparedness for extreme heat events.

Factors Affecting the Economic Burden Associated with Heat-related Illnesses

The results of Stage 2, presented in Table 4, indicate the factors that affect the economic burden associated with heat illnesses for different combinations of coping measures. The length of hospital stay (in days) has a significant impact on the economic burden. Specifically, the variable was found to be statistically significant in Stage 2, with a positive coefficient indicating that a longer stay is associated with a higher economic burden of heat-related illnesses. This suggests that measures aimed at reducing the length of stay, such as early detection and treatment of heat-related illnesses, can be effective in mitigating the economic burden.

Having a background disease and exposure to heat through work conditions seem to pose a greater impact on the economic burden of diseases, especially when multiple measures are adopted. A positive coefficient indicates that individuals with pre-existing health conditions are more likely to experience a higher economic burden of heat-related illnesses. This finding is consistent with other studies that have shown people with chronic diseases, such as cardiovascular disease, diabetes and respiratory illnesses, are more vulnerable to heat-related illnesses and have higher associated treatment costs (Aung et al., 2022). Gender was found to be statistically significant in both Stage 1 and Stage 2 of the study, with a positive coefficient indicating that

Table 4. Factors Affecting the Economic Burden Associated with Heat-related Illnesses.

	Economic Burden of Non-adoption (j = 1)		Economic Burden of Adoption of a Single Measure (j = 2)		Economic Burden of Adoption of Combined Measures (j = 3)	
Variables	Coef.	SE	Coef.	SE	Coef.	SE
Background diseases	0.297	0.184*	−0.455	0.637	0.115	0.091*
Personal experience with heat-related illnesses	0.036	0.127	−0.454	0.998	0.020	0.130
Exposure to heat in working condition	−0.095	0.055	0.156	0.367	0.163	0.110*
Length of stay	0.056	0.011*	0.063	0.012*	0.036	0.005***
Perceived individual anxiety	−0.087	0.093	−0.156	0.472*	0.115	0.062***
Knowledge	−0.154	0.045	−0.318	0.266	0.010	0.039*
Age	0.002	0.005***	0.031	0.039*	0.001	0.005**
Gender	0.296	0.137*	−0.739	0.651	0.133	0.143*
Education	−0.046	0.090	−0.254	0.312	−0.024	0.110
Household size	0.006	0.023*	−0.109	0.195	0.039	0.024***
Warning	0.127	0.236	1.359	0.942	−0.016	0.078
Warning intensity	0.311	0.172*	−1.330	0.474	0.008	0.106
Information source – TV	−0.147	0.215	−0.028	0.707	0.022	0.146
Information source – Authorities	0.036	0.241	−2.237	2.314	−0.054	0.088
Information source – Social media	0.161	0.256	−3.017	0.695	0.103	0.209
Constant	16.583	0.727	18.317	2.932	14.801	0.360
γ_1	−1.285	0.532	−0.282	0.661	−0.501	0.646
γ_2	1.212	0.479*	−0.509	0.579	0.417	0.565

Notes: *, **, *** significant at 10%, 5% and 1%, respectively. SE: Standard error.

women were more likely to adopt coping measures and experience a higher economic burden of heat-related illnesses. This finding is consistent with other studies that have shown women are more susceptible to heat-related illnesses and have a higher risk of morbidity and mortality compared to men. It is surprising to find that the study results did not align with the expectation that access to information would have a significant impact on reducing the economic burden associated with heat-related illness. This suggests that there may be barriers that deter the dissemination of information on heat-related illness, or it may not reach those who need it the most.

In general, the Stage 2 results suggest that adopting coping measures such as reducing length of stay and exposure to extreme heat, managing underlying medical conditions and improving access to information could effectively reduce the economic burden of heat-related illnesses. Policymakers and healthcare providers can utilise these findings to develop interventions and programs aimed at encouraging individuals to adopt these coping measures, thereby reducing the overall economic burden of heat-related illnesses.

Results of Estimated Treatment Effects of Adopting Coping Measures on the Economic Burden Associated with Heat-related Illness

Table 5 presents the average treatment effects of adopting coping measures on the economic burden of heat-related illness. The findings indicate that both single and combined coping measures are effective in reducing the economic burden of heat-related illnesses. Specifically, the adoption of a single coping measure is associated with a decrease of 0.146 (million VND) in the log of COI for ATT, while adopting combined coping measures is associated with a greater decrease of 0.170 (million VND) in the log of COI, which is equivalent to a reduction of 13.92% and 15.63%, respectively, compared to not using any coping measures. The unconditional treatment effects also show very similar results, with the adoption of a single coping measure resulting in a reduction of 10.41% in COI, while combined coping measures led to a reduction of 11.31%. Furthermore, it appears that combining multiple coping measures is more effective in reducing the economic burden of heat-related illnesses than relying on a single measure alone. The percentage reduction in COI associated with combined measures is larger than that of a single measure, for both

Table 5. Estimated Results of Treatment Effects of Adopting Coping Measures on the Economic Burden of Heat-related Illness.

		Adoption Status			Change in Outcome
Outcome Variables	Combinations	Adopting (j = 2,3) (a)	Non-adopting (j = 1) (b)	Treatment Effects (c) = (a) – (b)	(%)
Treatment effects on treated – ATT (log COI)	Single measure	16.61	16.76	−0.146*	−13.92
	Combined measures	16.73	16.90	−0.170***	−15.63
Unconditional treatment effects – UATE (log COI)	Single measure	16.14	16.25	−0.110***	−10.41
	Combined measures	16.70	16.82	−0.120***	−11.31

Note: *, **, *** significant at 10%, 5% and 1%, respectively.

ATT and UATE. This suggests that the adoption of multiple coping measures may be a more effective approach to reducing the economic burden of heat-related illnesses.

The findings of this study are consistent with previous studies that suggest adopting coping measures can reduce the economic burden of heat-related illnesses. For instance, Deng et al. (2020) found that using air conditioning, staying indoors during peak heat hours and wearing appropriate clothing can significantly lower the risk of heat-related illness and its associated economic burden. Likewise, Nunfam et al. (2019) indicate that employing coping measures can be an effective means of mitigating the economic burden of heat-related illnesses, and that combining multiple measures may be more impactful than using a single approach. Besides, our finding is consistent with previous studies that have compared ATT and UATE for various interventions such as education, healthcare and employment programs. For example, Dehejia and Wahba (1999) found that the ATT for a job training program was significantly larger than the UATE, indicating that the program was most effective for those who participated in it. Moreover, this study provided evidence-based information on how the level of adoption influences the effectiveness of coping measures in reducing the economic burden of heat-related illnesses.

Conclusions

This study explored the interplay between coping measures and the economic burden associated with heat-related illnesses in Central Vietnam. We employed a two-stage estimation strategy to investigate the factors that shape individuals' decisions to adopt coping measures and their effectiveness in reducing the economic burden of heat-related stress. Key drivers for choosing coping measures include background diseases, workplace heat exposure, perceived effectiveness, gender and educational attainment of household heads, and access to social media. The study also found that individuals with pre-existing health conditions and longer hospital stays faced higher economic burdens. Gender was significant in both stages, with women more likely to adopt coping measures and incur higher costs. However, general access to information had minimal impact.

We found strong evidence that adopting single or combined coping measures effectively reduces the economic burden of heat-related illnesses, with combined measures having a greater impact. The study highlights the importance of reducing heat exposure, prioritising vulnerable populations, raising awareness and promoting integrated approaches to mitigate costs. The findings provide valuable insights for policymakers and healthcare providers in designing interventions that encourage the adoption of coping strategies and alleviate the economic burden of heat-related illnesses in Vietnam. However, due to data limitations, further research is necessary to evaluate the long-term cost-effectiveness of these interventions.

Data Availability

Data from this study are available upon request.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Ethical Statements

The work received approval from the Human Research Ethics Committee of Hue College of Medicine and Pharmacy (Vietnam) and Queensland University of Technology Research Ethics Committee (Approval number: H2021/016).

Funding

The authors disclosed receipt of the following financial support for the research, authorship and/or publication of this article: This research is funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number 502.99-2020.36.

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Appendix A

Table A1. Symptoms Associated with Heat-related Illnesses.

	Mean	Std. Deviation
Cramps due to heatstroke	3.23	0.924
Heat stroke	3.92	0.822
Heat exhaustion/fatigue due to heat	3.71	0.888
Feeling constrained/unable to do activities that I enjoy	3.66	0.853
Headache	3.94	0.788
Sleepless	3.94	0.792
Disorientation/unable to function normally/unable to concentrate on work	3.55	0.871
Mentally exhausting/draining	3.99	0.711

Table A2. Exposure to Heat-related Illnesses at Work.

Items	%
No exposure	10.3
Little exposure	49.5
Moderate exposure	23.5
Frequent/high exposure	15.3
Very frequent/very high exposure	1.5

Table A3. Coping Measures to Tackle Heatwaves.

Coping Measures	%Yes
1. Buy/use air conditioner	54.1
2. Buy/use fan/ceiling fan	94.2
3. Plant trees around the house	83.4
4. Stay indoors/stay out of the sun	86.2
5. Shower several times a day	52.0
6. Use thin clothes	94.0
7. Work early in the morning or late in the evening	66.7
8. Swim	29.8
9. Upgrade/repair house features (e.g., thick walls, high ceilings, insulation)	36.1