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Impact of Depression on Activation and Summer Heat Adaptation in Older Adults With Cardiovascular Concerns: Empirical Research Quantitative

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ABSTRACT

Aim: To investigate the effects of depression on patient activation and summer heat adaptation, considering important contributory factors in older adults with increased cardiovascular health concerns on extremely hot days.

Design: Cross-sectional study adhering to the STROBE guidelines.

Methods: Between July and August 2020, a questionnaire survey was administered to 245 older adults at increased risk of cardiovascular diseases in rural areas. Data were collected utilising validated and reliable tools to assess patient activation, depression, summer heat adaptation, frailty, physical activity and other health-related characteristics. Hierarchical regression, mediation and path analyses were conducted to examine the association between activation, depression and summer heat adaptation, while controlling for covariates.

Results: Most participants exhibited the lowest level of activation (75.1%) and a low/moderate level of summer heat adaptation (80.4%). Depression negatively affected activation ($\beta = -0.247$), while its indirect effect on patient activation through summer heat adaptation was insignificant ($p > 0.05$). Education ($\beta = 0.380$) and a family history of cardiovascular disease ($\beta = 0.121$) positively influenced activation, while alcohol consumption had a negative influence ($\beta = -0.219$). When integrating the influence of these three contributory factors, the associative relationship between depression and activation through summer heat adaptation demonstrated a good model fit (chi-square = 8.944, $p > 0.05$; comparative fit index = 0.987; root mean square error of approximation = 0.045).

Conclusion: Improving older adults' activation for self-managing chronic conditions in summer requires tackling depression, enhancing heat adaptation and addressing concerns related to lack of education and alcohol consumption.

Patient or Public Contribution: Patients with cardiovascular diseases were involved in piloting the questionnaire and provided examples to address older adults' concerns related to self-management and heat adaptation.

1 | Introduction

Global warming has increased the frequency and intensity of heat hazards, such as heat waves, leading to an increase in heat-related illnesses and deaths (Romanello et al. 2023). The COVID-19 pandemic has exacerbated the adverse effects of rising temperatures. Under this condition, nurses were called for urgent actions, ranging from policymaking, prevention to direct care provision, to protect vulnerable people from the harm of extreme heat and other climate-related events (Catton 2023). Older adults (aged ≥ 65), particularly those with cardiovascular diseases (CVDs), are among the most vulnerable to the adverse health impacts of heat exposure (Romanello et al. 2023). Between 2013 and 2022, heat-related deaths among older adults increased by 85% compared to 1990–2000, far exceeding the expected increase of 38% if the temperatures had remained stable (Romanello et al. 2023). Adequate patient activation—comprising good knowledge, skills and confidence in self-management (Hibbard 2017)—and effective summer heat adaptation are crucial for older adults with chronic conditions to combat and survive life-threatening heat-related illnesses during hot summers. However, severe depressive symptoms may hinder one's ability to cope with such adversities.

This study was anticipated to address our concerns about how and to which degree depression influences the vulnerable older adults' activation to self-manage chronic conditions (e.g., CVDs), including taking adaptive behaviours to reduce the threat of heat-related illness in summer. With such knowledge, nurses could develop and adopt more appropriate programs to incorporate the tackling of factors limiting older adults' self-management of complicated health conditions during hot summer days and beyond.

Older adults with CVDs were more susceptible to life-threatening heat-related illnesses compared with their counterparts without them (Gravel et al. 2021). They often have compromised physiological responses even prior to the initiation of thermoregulatory behaviours, compared to younger ones (Romanello et al. 2023; Vu et al. 2019). More attention therefore should be drawn to this group of people, especially those in rural areas, for better health.

2 | Background

Like the global trends, CVDs—including coronary heart disease, heart failure, hypertension and stroke—remain the leading cause of morbidity and mortality in mainland China (Ning 2021). Recent statistics indicate that approximately 330 million individuals had CVDs, accounting for 48.46% of deaths in 2021 (The Writing Committee 2022). Compared to urban populations, rural populations are experiencing higher rates of CVD cases and deaths, suggesting the worsening consequences of CVDs since many more older adults with CVDs reside in rural areas and are weaker at self-managing CVD-related problems (The Writing Committee 2022). With the rapid growth of the older population, the burden of CVDs and related deaths on patients, their families, health systems and society increases substantially.

High (patient) activation indicates the possession of adequate knowledge, skills and confidence at managing one's own symptoms/problems associated with certain chronic conditions (Hibbard et al. 2004). For patients with chronic non-cancerous health conditions, from obesity to multiple comorbidities, having high activation implies that they are likely to be effective at self-management, decision-making and health behaviour changes toward better outcomes (Newland et al. 2021). Conversely, low activation is associated with poor outcomes, such as increased 30-day mortality in patients with heart failure (Tecson et al. 2019). To maintain health during very hot days, older adults with CVDs require timely information and taking adaptive behaviours to reduce the harm of extreme heat and heated environments (Vu et al. 2019), indicating increased activation compared to the usual status for self-managing existing chronic conditions.

Self-regulation skills are essential to performing self-management behaviours including taking self-regulation or adaptive behaviours during hot summer days (Newland et al. 2021). Such behaviours are integral parts of the behavioural presentations of both patient activation and summer heat adaptation (Hibbard 2017; Vu et al. 2019), suggesting their connection or associative relationship at behavioural and underpinning levels.

Numerous factors—including age, sex, marital status and many other demographic, socioeconomical, psychological and behavioural and disease-specific factors—influence patient activation in older adults with CVD-related conditions such as dyslipidemia, obesity, diabetes, hypertension, smoking and drinking (Rapelli et al. 2020; Golubinski et al. 2020). They increase the risk of CVDs or subsequent major adverse cardiac events (MACEs, e.g., death, myocardial infarction, stroke and heart failure) following an initial CVD incident (Roohafza et al. 2023; Vaduganathan et al. 2022). High activation in older adults with CVD-related conditions contributed to the reduction of CVDs and MACEs (Kearns et al. 2020; Newland et al. 2021).

Depression is one of the major psychosocial/psychological factors and the most widely recognised mental health problem that affects patient activation (Golubinski et al. 2020). It substantially increased the risk of CVDs and MACEs (Shiga 2023; Zhang et al. 2018). As revealed, depression is highly prevalent among patients with hypertension, coronary heart disease and diabetes, negatively impacting treatment and prognosis, while poorer outcomes and prognosis were found in those with more depressive symptoms (Qiu et al. 2020; Zhang et al. 2018). Dunlay et al. (2017) identified a negative effect of depression on activation in patients with heart failure, leading to adverse outcomes (e.g., increased mortality and patient dissatisfaction), but the others did not (Carey et al. 2018; Tecson et al. 2019).

Negative effects of depression on summer heat adaptation may also exist. The rising air temperature and heat waves in summer have been linked to increased mental problems like depression and decreased heat adaptation in older adults with CVD-related conditions (Liu et al. 2021; Romanello et al. 2023). Motivating individuals with depression to take actions proactively or actively,

such as adapting to a heated environment or self-managing worsened health issues—indicating increased activation—is challenging, given the difficulties for those with depression to initiate and maintain actions (Qiu et al. 2020). We thus conjecture that depression was negatively associated with summer heat adaptation and patient activation in older adults with CVD-related conditions, respectively.

Furthermore, repeated seasonal exposure to extreme heat in summer can lead to an accumulated effect on one's heat adaptability (such as the capability to take beneficial action) or heat adaptation (such as adjustment through protective behaviours), resulting in seasonal acclimatisation (Vu et al. 2019). Many factors threaten one's heat adaptation in summer, including age, low socioeconomic status, living alone, lack of social outings, use of mobility aids, comorbidities, use of medications and so forth (Gravel et al. 2021; Vu et al. 2019). Higher heat adaptation means having more heat-protective behaviours during heat stress in summer, indicating higher activation; consequently, heat-related illnesses are less likely to occur or deteriorate, suggesting a positive association between summer heat adaptation and patient activation.

Frailty is an age-related syndrome common in older adults, characterised by accumulated physical, psychological and social deficits, leading to increased vulnerability to various health threats such as heat stressors. Compared to non-frail individuals, frail and pre-frail older adults have a significantly higher risk of CVDs (Veronese et al. 2017) and a higher prevalence of depression, hypertension, falls, disability and multimorbidity, especially among those with a history of coronary heart disease (Damluji et al. 2021). Frailty appears to increase the risk of adverse outcomes and could negatively influence beneficial actions (e.g., activation and heat adaptation), warranting further investigation.

Regular physical activity is associated with reduced frailty and depression in older adults with CVD-related conditions (Damluji et al. 2021). However, even light outdoor exercise in a heated environment during summer can be detrimental to health, increasing the risk of heat-related illnesses (Romanello et al. 2023). Those with better heat adaptation were more likely to know when and how to adjust (i.e., increase or reduce) their physical activity to mitigate the impact of heat on their health (Vu et al. 2019). More intentional self-regulation and adoption of appropriate physical activity (e.g., more in the early morning but less at noon) indicate higher activation for self-managing health problems. Thus, the association between physical activity and patient activation/heat adaptation may not be that strong and clearly show a positive/negative relationship.

Among the mounting body of research on patient activation globally, few studies have been conducted in mainland China (Zeng et al. 2019; Zhang et al. 2021). Nearly all these studies recruited both older and younger adults aged <65. In these studies, the 13-item Patient Activation Measure (PAM-13)—a unique instrument with satisfactory psychometric properties to assess and grade patient activation (Hibbard 2017)—was utilised to measure activation. However, none investigated the impact of environmental factors such as high air temperature, mental factors such as depression or physical factors such as frailty on activation in the Chinese population.

In summary, existing evidence suggests that depression negatively impacts patient activation and summer heat adaptation in older adults with CVD-related conditions, increasing the risk of heat-related illness and the deterioration of underlying health conditions. It remains unclear whether the effect of depression on summer heat adaptation further influences the association with activation (i.e., mediating effect through summer heat adaptation), particularly when considering other contributory factors such as frailty, physical activity, multimorbidity and so forth.

2.1 | Guiding Framework

Patient activation is crucial to the consumer-directed health plans approach and the collaborative chronic illness care model, which necessitates patient participation in decision-making and other actions for self-managing chronic conditions (Hibbard et al. 2004). It stressed the roles of activated patients in engaging in the acquisition and translation of relevant knowledge, skills, beliefs and confidence into everyday self-management practice. As recognised, patient activation is a prerequisite to the effective self-management of chronic illness (Golubinski et al. 2020).

According to the Individual and Family Self-Management Theory (IFSMT), satisfactory execution of self-management behaviours can prevent, slow down, stabilise or even stop the progression of problems associated with certain chronic conditions (i.e., Distal Outcomes) (Bauer et al. 2023; Ryan and Sawin 2009). Such executive performance requires patients' proactive, active and continuous efforts to gain and use relevant knowledge and beliefs, self-regulation skills and social facilitation skills (e.g., instrumental social support) along the Self-Management Process (Bauer et al. 2023; Ryan and Sawin 2009), indicating high patient activation.

The Context for self-management consists of risk and protective factors which could be condition-specific (e.g., multimorbidity, frailty and certain CVDs), physical and social environment (e.g., health care access and transportation) or individual and family factors (e.g., literacy or educational level, family structure and functioning like being married and living with children). These contextual factors influence both Self-management Process and Outcomes (Bauer et al. 2023; Golubinski et al. 2020). Patient activation rightly captures the crucial elements of Self-management Process (e.g., knowledge and beliefs and self-regulation skills) and links with the most important Proximal Outcomes (i.e., self-management behaviours) (see Figure 1).

Summer heat adaptation could be the outcome of patient activation. Considering the impact of accumulated seasonal effect, summer heat adaptation is like a contextual factor, representing habitual adaptability or adaptive behaviours developed over time. It is also like a Self-management Process concept, reflecting the use of appropriate knowledge, beliefs and self-regulation skills to reduce exposure to heat in daily life. We prefer to treat

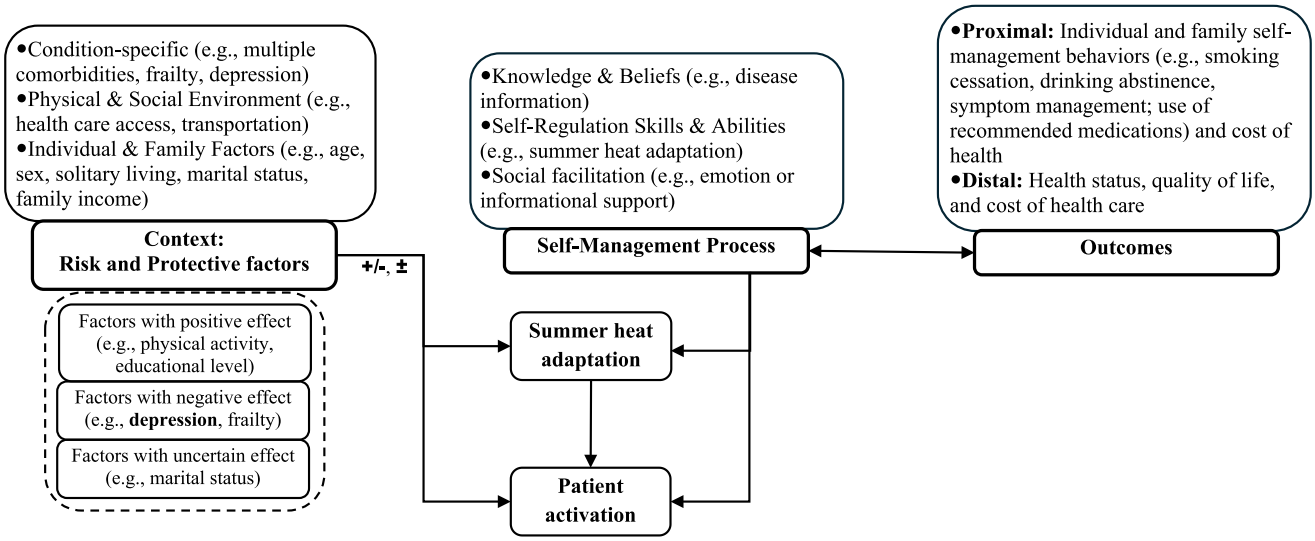

FIGURE 1 | Guiding framework about patient activation and relevant factors in alignment with the Individual and Family Self-management Theory.

it as an element of Self-management Process since exposure to extreme heat in present summer could stimulate the learning and adoption of potential adaptive behaviours for immediate benefits.

As aforementioned, some important contextual factors (e.g., depression, frailty, multimorbidity and physical activity) did not consistently show definitive effects—whether negative or positive—on patient activation and/or summer heat adaptation. This is the case especially when the other influencing factors (i.e., background/contextual covariates) are taken into consideration. The current study was expected to generate a clearer picture about the negative effects of contextual factors—especially those critical for older adults with CVDs such as depression and frailty—on patient activation and whether there existed any working paths to reduce such effects for higher activation and better self-management.

3 | The Study

3.1 | Aim and Objectives

This study aimed to investigate the effects of depression on patient activation and summer heat adaptation among older adults with increased cardiovascular health concerns (the target population) during extremely hot days.

3.2 | Hypotheses and Study Approach

The primary hypothesis was that summer heat adaptation mediates the effect of depression on activation in this target population. The secondary hypothesis was that certain contextual factors maximally explain the variance in patient activation in association with depression and summer heat adaptation in the target population. The quantitative approach was adopted to estimate the degree of effect of depression and the percentage of variance to be explained by important contributory factors.

4 | Methods

4.1 | Design

A cross-sectional questionnaire survey was conducted among rural older adults with CVD-related conditions to examine their activation and relevant contextual factors. This report was prepared according to the recommended guidelines for cross-sectional studies, that is, STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) (von Elm et al. 2007).

4.2 | Instruments With Validity and Reliability

The questionnaire comprised a background information sheet and existing scales to collect data on the participants' characteristics, concerning our primary concerns over patient activation, summer heat adaptation, depression and contextual factors ranging from condition-specific, physical and social environments to individual and family factors.

Weight, height, waist circumference and blood pressure were measured utilising standard methods, whereas other background data were retrieved from the participants' health records and crosschecked. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Obesity and hypertension were diagnosed according to national criteria (National Health Commission 2017).

To minimise the response burden, the shortest versions of the existing scales with satisfactory psychometric properties (e.g., content validity index [CVI] > 0.80, internal reliability Cronbach's alpha > 0.70), indicating acceptable validity and reliability (DeVellis 2017), were selected to measure activation, depression, frailty, (overall) physical activity and summer heat adaptation.

The 10-item Patient Activation Measure (PAM-10) is the shortest form of activation measure utilised to assess knowledge, skills and confidence in self-managing chronic conditions

(Hibbard 2017). Such a concise scale was preferred for initial assessment and quick screening compared to the longer ones (Hibbard et al. 2004). Typical items measuring relevant knowledge, skills and confidence include the following: "I know what each of my prescribed medications do"; "I have been able to maintain the lifestyle changes for my health that I have made" and "I am confident I can figure out solutions when new situations or problems arise with my health condition." Each item was rated on a four-point scoring scheme ranging from "strongly disagree" (1) to "strongly agree" (4). A scale score of 1–100 was computed with raw item scores to determine activation levels ranging from the lowest to the highest: disengaged and overwhelmed (L1), being aware but still struggling (L2), acting and gaining control (L3) and maintaining behaviours and pushing further (L4). Higher scores or levels indicate greater activation of self-management. The PAM-10 has good psychometric properties, similar to the commonly utilised PAM-13 (Hibbard 2017). It exhibited satisfactory internal reliability (Cronbach's alpha [α] = 0.885) and a 2-week test–retest reliability (intraclass correlation coefficient [ICC] = 0.946) in this study.

The Geriatric Depression Scale (GDS) is extensively utilised to screen older community dwellers for depression. The short version (GDS-15) contains only half of the statements on depressive symptoms. Total correct answers (either yes or no) for each statement were included and the scale's score ranged from 0 to 15; a score of 5–8 suggested "suspected depression," while a score of 8 or above indicated "depression" (Shin et al. 2019). The higher the score, the greater the number of depressive symptoms. GDS-15 exhibited good validity and reliability among older adults in China in a prior study as well as in this study (α = 0.849; ICC = 0.916).

Physical frailty was assessed utilising the Vulnerable Elders Survey Scale (VES-13), a well-known screening tool for identifying vulnerable older adults who require community treatment. Different scoring schemes were utilised to rate the vulnerabilities associated with age, overall health, physical limitations and functional disability. The scale's score can range from 0 to 10 (with a score of ≥ 3 being classified as "vulnerable," and ≥ 7 as "highly vulnerable") indicating substantially increased risk of functional decline or death in the subsequent 2 years compared with those that are non-vulnerable (Andrade et al. 2021). The Chinese version exhibited sound validity and reliability in a prior study, whereas this study revealed lower internal reliability (α = 0.586) but a higher 2-week test–retest reliability (ICC = 0.798).

The short form of the International Physical Activity Questionnaire (IPAQ-SF) was utilised to assess the days and time spent on vigorous and moderate physical activities, walking and sitting over the past 7 days. The level of physical activity (such as low, moderate or high) was determined utilising composite criteria for total energy consumption, time duration and activity frequency. The most recent study in China corroborated evidence regarding its validity and reliability among adults aged 30–70 (Hu et al. 2015). The current study revealed a high 2-week test–retest reliability (ICC = 0.897).

Heat adaptation was measured utilising the 15-item Summer Heat Adaptability Scale (SHAS-15), which assesses summer heat-related risk awareness, coping attitudes and adaptive behaviour on high-temperature days (Wang 2018). Exemplary questions about awareness, coping and behaviours include the following: 'Are there numerous high temperature days in summer in this place'; 'Do you proactively tell others about healthcare knowledge related to high temperature weather' and 'How often do you utilize window curtains to block the heat.' A four-point Likert scale was utilised to rate the degree of adaptability of each item, ranging from the lowest (1 = not at all/never) to the greatest (4 = very much/always). The total of item scores forms the scale's score ranging from 15 to 60, with higher scores indicating greater adaptability to summer heat. SHAS-15 exhibited excellent content validity and acceptable internal reliability (α = 0.725) among older community dwellers in China (Wang 2018). This study revealed marginal internal reliability (α = 0.600) as well as a high 2-week test–retest reliability (ICC = 0.820).

4.3 | Sampling and Recruitment

Participants were recruited from a rural health centre in the hilly areas of eastern China, which provides primary care services for 33,767 village residents. All residents have their electronic health records included in the health information system of the township hospital upon their initial medical consultation at the centre.

4.4 | Sample Size and Power

The sample size was determined to provide adequate power to detect associations between activity and the studied physical, psychological and behavioural variables. By utilising the Power Analysis & Sample Size (PASS) 2019 (NCSS, Kaysville, Utah), it was estimated that a sample size of at least 192 participants would enable the study to detect a correlation coefficient between variables with a value as small as 0.2 with 80% power at a 5% level of significance (2-sided). Furthermore, enabling for up to a 30% non-response rate, 274 participants were approached.

4.5 | Population and Sample

Over one-fifth of the village residents (20.6%, n = 6969) were older adults (aged ≥ 65). Most residents (88.5%, n = 6166) had their own electronic health records with the above health centre to access appropriate services. Over half of the registrants (53.3%, n = 3285) were diagnosed with CVDs or related conditions, suggesting an increased risk of further CVDs or subsequent MACEs. Utilising an online randomiser, 274 participants were randomly selected from potentially eligible older residents (n = 1338) who met the following criteria:

4.6 | Inclusion and Exclusion Criteria

The inclusion criteria comprised village residents (aged ≥ 65) whose electronic health record documents indicated at least one diagnosis of CVD or related risk conditions, including coronary heart disease, hypertension, diabetes, hyperlipidemia,

obesity, smoking and family history of CVD. Exclusion criteria were as follows: Village residents with severe physical and mental problems (e.g., hearing loss, cancer, paralysis, dementia or schizophrenia) that heavily influence their ambulance or communication with others. People with such severe conditions have difficulties in performing certain self-management activities, which limits their activation to narrowed areas of concern, thus requiring a more specific instead of a general approach to examining the presentation of activation.

4.7 | Data Collection

Post screening the retrieved diagnoses of any CVD or related risk conditions mentioned above, the second author (LHW, community head nurse) called eligible older adults to inquire about their interest in participating post elucidating the study. Those who agreed to participate in the study were appointed. The survey questionnaire was administered to the participants' homes during the hottest summer days from July 26 to August 18, 2020, according to the meteorological prediction by the National Meteorological Administration. Moreover, a general practitioner joined the home visits as a result of their familiarity with the participants and provided brief consultations when needed. Two research assistants assisted with the data entry and accuracy checks.

4.8 | Data Analysis

The SPSS 29 and AMOS 29 (IBM Corp., Armonk, New, USA) were utilised for all analyses. The significance level was set at $p < 0.05$ (two-sided). Appropriate descriptive statistics (e.g., mean, standard deviation [SD], frequency and percentage) were utilised to summarise and present the data. Hierarchical multiple regression analysis was conducted to examine the associations between activation and all other measured background characteristics and variables. Specifically, all background characteristics were entered as independent variables in the first block of multiple regression, with activation as the dependent variable. The measured physical and psychosocial variables (depression, summer heat adaptation, frailty and physical activity) were entered into the second regression block.

The mediation effect was analysed utilising the PROCESS program to determine whether there was a significant indirect effect of depression on activation through summer heat adaptation. The path from depression to activation, both directly and through summer heat adaptation, was analysed utilising different sets of important contributory covariates with the maximum likelihood method. Model fit indices were compared to identify the model that met the criteria for a good fit.

4.9 | Ethical Considerations

This study was approved by the institutional ethics committee (No. 2020-RN032) and abided by the Declaration of Helsinki. All the participants signed an informed consent form prior to data collection at home. Post the introduction of the study, the concepts of voluntary participation, withdrawal without any reason or negative consequences, benefits relative to risks and privacy protection (i.e., confidentiality in the storage and academic utilisation of anonymous data) were elucidated until the end of questions from participants and their family members.

5 | Results

A total of 245 participants from a randomly selected sample of 274 eligible participants were included in the survey. The response rate was 89% and all participants provided valid responses to the survey. The non-response cases (11%, $n = 29$) primarily resulted from domestic migration or severe physical or communication difficulties and scarcely from refusal, death or cancer.

5.1 | Subjects

Participants' ages ranged from 65 to 90 years (mean 73.3; SD, 5.78). More than half were male (58%), married (71.4%), lived with their spouses (70.5%), had children (9.4%), had limited education (84.5% primary or below) and had a household income (approximately $138 per month). All participants had medical insurance with governmental complementation and nearly 10% of them received subsidies for social security reasons owing to poverty, disability or having no family. Almost 60% of the participants had more than one diagnosed disease and over half were obese: high waist circumference, 34.7% ($n = 85$); high BMI, 7.8% ($n = 19$); high waist circumference and BMI, 15.9% ($n = 39$). The participants with hypertension (67%, $n = 164$) were primarily diagnosed with systolic hypertension (28.6%, $n = 70$) or both systolic and diastolic hypertension (36.3%, $n = 89$). About half of the participants had a family history of CVDs, and a high proportion were drinking or smoking frequently or always, that is, heavy drinkers (21.6%) or heavy smokers (38%). Additional details are provided in Table 1.

5.2 | Descriptive Characteristics of Measured Variables

Majority of the participants (71%) had the lowest level of activation and minimal reached the highest level (1.6%, $n = 4$), indicating very limited knowledge, skills and confidence in self-managing chronic conditions. Approximately half of the participants (51%) had more than five or eight depressive symptoms, suggesting 'depression' or 'suspect depression,' respectively. Slightly more than one-fifth (22%) were vulnerable or very vulnerable, nearly all of whom were physically inactive, at the low level of physical activity (20.4%). Table 2 presents this in more detail.

5.3 | Multiple Regression Analysis

The normal P–P plot, scatterplot of residual plots against predicted plots, Durbin-Watson test (1.910 within the range of 0 to 4), variance inflation factors (VIFs; all < 5) and Mahalanobis distance test (all Ps > 0.001) exhibit that all the assumptions of linear regression are satisfied regarding normality, homoscedasticity, independence of observations, absence of collinearity

TABLE 1 | Participants' basic characteristics ($N = 245$).

Group	Subgroup[a]	*n*	%
Age (years) (mean 73.23, SD 5.783)	65–75	158	64.5
	≥ 75	87	35.5
Sex	Female	103	42.0
	Male	142	58.0
Education level	< Primary	101	41.2
	Primary	106	43.3
	≥ Middle	38	15.5
Marital status	Married	175	71.4
	Others	70	28.6
Living status	Alone	49	20.0
	With others	196	80.0
Family income/month (Chinese Yuan)	< 1000	172	70.2
	≥ 1000	73	29.8
Governmental subsidies	No	222	90.6
	Yes	23	9.4
Obesity	No	102	41.6
	Yes[b]	143	58.4
Hypertension	No	81	33.1
	Yes[c]	164	66.9
Smoking	No	152	62.0
	Yes	93	38.0
Drinking	No	192	78.4
	Yes	53	21.6
Diseases (*n*)	0	18	7.3
	1	81	33.1
	2	85	34.7
	≥ 3	61	24.9
Family history of CVD[d]	No	121	49.4
	Yes	124	50.6

[a]For regression analysis, the first subgroup is reference and valued as 0, while the remaining subgroups are valued as 1 to 4 in order, depending on the total number of subgroups.
[b]Including those with body mass index and/or waist circumference reaching the criteria of obesity.
[c]Including all with high systolic and/or diastolic blood pressure.
[d]Approximately 92.4% ($n = 224$) participants had diagnosed CVDs, while each of the others had at least three CVD-related conditions (7.3%, $n = 18$) indicating an increased risk of CVD or major adverse cardiac events.

and absence of outliers, respectively (Table 3; Figures S1 and S2 in the Supporting Information). The hierarchical regression analysis revealed that the depression level (GDS-15 total score, $\beta = -0.247$) and degree of summer heat adaptation (SHAS-15 total score, $\beta = 0.194$) were significantly associated with the level of activation (PAM-15 total score) post adjusting for background characteristics. These two variables elucidated a further 6.3% of variance of activation ($p < 0.001$)—summer heat adaptation and depression contributing 2.7% and 3.6% to the variance, respectively—in addition to the background characteristics ($R^2 = 49.5\%$), while years of age ($\beta = -0.138$), level of education ($\beta = 0.380$), drinking ($\beta = -0.219$), multimorbidity ($\beta = 0.115$) and family history of CVDs ($\beta = 0.121$) were significantly associated with activation.

5.4 | Mediation Effect Analysis

Model 4 was suitable for analysing the mediation effect from depression to activation through summer heat adaptation, with five significant contributory factors as covariates, namely: age, level of education, number of diseases, family history of CVD and alcohol consumption. The direct effect of depression on activation was significant (coefficient −0.596, 95% Bootstrap confidence interval (CI) −0.781, −0.347; $p < 0.001$), but the indirect effect through summer heat adaptation was not (coefficient −0.032, 95% CI −0.093, 0.019; $p > 0.05$). The total effect model elucidated 50.8% of the variance in activation ($p < 0.001$). See Table S1 in the Supporting Information.

5.5 | Path Analysis

The default path was drawn from depression to activation, with summer heat adaptation as the mediating variable and the significant background characteristics (i.e., age, level of education, number of diseases, family history of CVD and alcoholic drinking) as covariates. The maximum likelihood method, with modifications for large modification indices, was utilised to analyse the model fit of the default path. By sequentially excluding two covariates (i.e., age and number of diseases) with the smallest contribution to the variance in activation, the model fit indices improved. Furthermore, adding three bidirectional paths between level of education, depression, summer heat adaptation and alcohol consumption resulted in all indices meeting the criteria for a good model fit: chi-square/degrees of freedom = 1.491, $p = 0.177$ thereby > 0.05; comparative fit index (CFI) = 0.987; adjusted goodness-of-fit index (AGFI) = 0.987; standardised root mean square residual (SRMR) = 0.044; root mean square error of approximation (RMSEA) = 0.045 and Tucker-Lewis index (TLI) = 0.968. See the three-covariate path diagram in Figure 2 and the model comparison in Tables 4 and S1 as well as Figure S3 in the Supporting Information.

6 | Discussion

In this study, few participants reached the highest level of activation (L3, $n = 1$) or maintained healthy behaviours and moved forward (L4, $n = 3$). The low proportion is in great contrast to the findings in developed societies; for example, 86.5% of older patients required advanced heart failure therapy (Carey et al. 2018). Enhancing the activation of older adults is imperative for improving the self-management of chronic conditions in rural China.

To address our hypotheses, this study identified several contextual factors (i.e., age, level of education, number of diseases,

TABLE 2 | Participant characteristics measured by existing scales ($N = 245$).

Scales	Score[a]		Subgroups		
	Mean	SD	Category	*n*	%
10-item Patient Activation Measure (PAM-10)[b]	40.906	7.847	L1	184	75.1
			L2-L4	61	24.9
15-item Summer Heart Adaptability Scale (SHAS-15)	38.106	4.336	Low	57	23.3
			Moderate	140	57.1
			High	48	19.6
15-item Geriatric Depression Scale (GDS-15)	5.306	3.508	Not depressed	121	49.4
			Suspected depression	59	24.1
			Depressed	65	26.5
13-item Vulnerable Elders Survey (VES-13)	2.167	2.364	Not vulnerable	191	78.0
			Vulnerable	29	11.8
			Very vulnerable	25	10.2
Short form of International Physical Activity Questionnaire (IPAQ-SF)	NA	NA	Low level	50	20.4
			Moderate level	69	28.2
			High level	126	51.4

Abbreviations: GDS-15, 15-item Geriatric Depression Scale; IPAQ-SF, Short Form of International Physical Activity Questionnaire; NA, not applicable; SHAS-15, 15-item Summer Heat Adaptability Scale; VES-13, 13-item Vulnerable Elderly Survey scale.
[a]For regression analysis, all variables scores were entered, while the score of physical activity level is 0, 1 and 2 for low, middle and high levels, respectively.
[b]Most participants were at the lowest (L1 = being disengaged and overwhelmed) or the second lowest level of activation (L2 = becoming aware but still struggling; 23.3%, $n = 57$). Very few ($n = 4$) participants reached the highest (L4 = maintaining behaviours and pushing further; 0.4%, $n = 1$) or the second highest level of activation (L3 = taking action; 1.2%, $n = 3$).

family history of CVDs and alcohol consumption) in addition to depression and summer heat adaptation that explained over half of the activation variance. This is consistent with the study about activation in adult Chinese (median age = 65 years) with heart failure regarding the contribution of certain factors (i.e., age, education level and depression) but not living arrangements (i.e., alone or with others; Wei et al. 2025).

Depression and summer heat adaptation exhibited divergent effects on activation when controlling the effects of pre-identified covariates (see Table 3). This study substantiates the evidence of the negative effects of depression on activation (Newland et al. 2021) and summer heat adaptation (Romanello et al. 2023; Vu et al. 2019). As revealed, depression is an independent risk factor for CVDs; it can synergize with multimorbidity to aggravate age-related frailty (Qiu et al. 2020), thus may further limit older adults' activation for self-management and independent living. We did find a small effect to support this inference (see Table 3): the more the disease, the higher the activation. The increase of diseases often requires more pharmaceutical, psychosocial and lifestyle resolutions, which drives patients to increase their activation for enhanced health and self-management. In our study, nearly three-fifths of the participants exhibited more than one diagnosed disease, nearly one-fourth had at least three diseases (i.e., multimorbidity) and all had at least three risk factors of CVDs, including an older age (≥ 65), obesity, drinking, smoking, high blood pressure and a family history of CVD (see Table 1). The number of diseases roughly reflects the severity or complexity of multimorbidity (Ryan and Sawin 2009). Strong professional support is crucial for patients to comprehend and coordinate the administration of complicated treatments (i.e., social facilitation skills in view of the IFSMT [Bauer et al. 2023]), including polypharmacy, psychosocial interactions and lifestyle modifications. Nurses thus could play a significant role in assisting the integration of different treatments for older adults with multimorbidity in any settings.

Compared to the other seasons, especially the winter season, there is a lower incidence of depression in summer, except in flood-prone areas (O'Hare et al. 2016). However, we identified approximately one-fourth of the participants as cases with depression or suspected cases (see Table 2). This quantity of cases warrants further investigation regarding whether heat adaptation mediates the effect of depression on activation in the other older population given global seasonal, meteorological and geological variances, even though we did not find any significant effect.

The level of education had the strongest positive effect on participants' activation with a coefficient greater than the combined absolute coefficients of heavy drinking and age in all the models involving different covariates (see Table S1 in the Supporting Information). It also influenced summer heat adaptation, depression and alcoholic drinking to a certain degree through modifying the variance of these covariates (see Figure 2). Good education thereby is important for activation, consistent with its working mechanism and the others' findings (Wei et al. 2025): more education means better ability to develop relevant

TABLE 3 | Linear regression analysis results.

	Unstandardized Coefficients	Standardized Coefficients			Collinearity Statistics
Independent variables	**B**	**Beta**	**t**	**Sig.**	**VIF**
(Constant)	**39.846****		5.394	**<0.001****	
Age (years)	**−0.188***	**−0.138***	−2.453	**0.015***	1.630
Being female	−1.289	−0.081	−1.321	0.188	1.941
Level of education	**4.206****	**0.380****	5.943	**<0.001****	2.101
Being married	1.712	0.099	1.236	0.218	3.276
Live with others	−0.104	−0.005	−0.069	0.945	3.053
Family income/month	0.594	0.035	0.628	0.531	1.567
Governmental subsidies	1.018	0.038	0.773	0.440	1.235
Obesity	−0.265	−0.017	−0.359	0.720	1.111
Hypertension	−0.924	−0.055	−1.211	0.227	1.077
Smoking	−0.345	−0.021	−0.415	0.679	1.362
Alcoholic drinking	**−4.161****	**−0.219****	−4.063	**<0.001****	1.489
Multimorbidity (Number of diseases)	**0.990***	**0.115***	2.194	**0.029***	1.401
Family history of CVD	**1.892***	**0.121***	2.567	**0.011***	1.136
GDS-15	**−0.552****	**−0.247****	−4.276	**<0.001****	1.706
IPAQ-SF	−0.495	−0.050	−0.918	0.360	1.514
SHAS-15	**0.351****	**0.194****	3.733	**<0.001****	1.386
VES-13	0.043	0.013	0.217	0.828	1.806

Note: Dependent variable: 10-item Patient Activation Measure (PAM-10).
Abbreviations: CVD: cardiovascular disease; GDS-15: 15-item Geriatric Depression Scale; IPAQ-SF: Short Form of International Physical Activity Questionnaire; NA: not applicable; SHAS-15: 15-item Summer Heat Adaptability Scale; VES-13: 13-item Vulnerable Elderly Survey scale; VIF: variance inflation factor.
* $p < 0.05$; ** $p < 0.001$.

knowledge, skills and confidence, leading to higher activation (Hibbard et al. 2004). Educational interventions in a language suitable for those without adequate schooling experience would be conducive to activation and self-management in rural older adults. Given the lack of evidence regarding activation-focused interventions and the controversial effects of alcohol consumption on CVDs (Cuevas et al. 2021; Kearns et al. 2020; Hu et al. 2022), more activation-tailored programmes should be attempted to target certain groups of older adults (e.g., those with drinking problems) to confront heat threats in the summer.

A salient negative effect of heavy drinking (such as drinking alcohol frequently or very often) on activation was brought to the surface in this study. The drinking variable was retained in all identified models (see Table S1). The debate on the controversial effects of alcoholic drinking continues, centring on the cut-offs or thresholds for a fundamental change from beneficial to harmful (Hu et al. 2022). Nonetheless, a consensus has been reached regarding the impairing effect of heavy drinking on patient activation and health (Wolinsky et al. 2017). We found a much higher proportion of heavy smokers (such as smoking frequently or very often) as opposed to heavy drinkers (38% vs. 21.6%), but, different from the others' findings (Wolinsky et al. 2017), heavy smoking was not a significant covariate of patient activation ($p > 0.05$).

A family history of CVDs exhibited a positive impact on patient activation, suggesting the important contribution of a relatively more CVD-knowledgeable family environment. Family support, whether emotional, economic or functional, is an essential source of social support within the family, which does not necessitate living with family members, although it is relatively easier to gain support if all family members live together (Bauer et al. 2023; Ryan and Sawin 2009). In this study, living with a spouse and/or children, having a lower household income or having social security subsidies did not significantly influence patient activation. However, Gleason et al. (2016) identified the importance of enhanced employment levels and conditions, indicating better household income, marriage, living with others and social support. The impact of socioeconomic status requires further investigation among urban older adults who may have higher incomes (Zeng et al. 2019).

This study also revealed the small effect of age on activation as the others (Wei et al. 2025). The effect of actual age instead of graded age (one point for age 75 to 84 and three points for

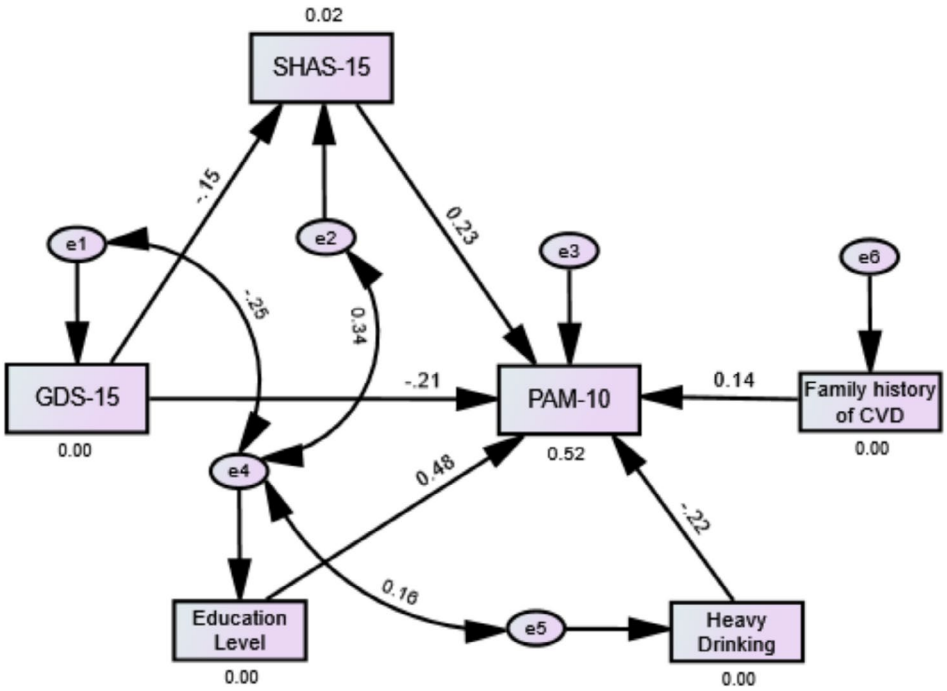

FIGURE 2 | Three-covariate path diagram with standardised estimates[a]. [a]All coefficients were significant (i.e., $p < 0.05$). CVD, Cardiovascular disease; GDS-15, 15-item Geriatric Depression Scale; IPAQ-SF, Short Form of International Physical Activity Questionnaire; PAM-10, 10-item Patient Activation Measure; SHAS-15, 15-item Summer Heat Adaptability Scale; VES-13, 13-item Vulnerable Elderly Survey scale.

TABLE 4 | Comparison of model fit indices between the paths with different covariates.[a]

		Three-covariate model		Four-covariate model		Five-covariate model	
Model fit indices	**Criteria**	**Modified**	**Unmodified**	**Modified**	**Unmodified**	**Modified**	**Unmodified**
Chi-square (χ^2)	The smaller, the better	8.944	67.234	23.172	105.206	56.246	166.119
Degree of freedom (df)	NA	6	9	10	14	16	21
χ^2/df	< 3	1.491	7.47	2.317	7.515	3.515	7.91
p	> 0.05	0.177	< 0.001	0.010	< 0.001	< 0.001	< 0.001
Standardised root mean square residual (SRMR)	< 0.05	0.0437	0.1287	0.068	0.149	0.0958	0.156
Root mean square error of approximation (RMSEA)	< 0.06	0.045	0.163	0.683	0.163	0.102	0.168
Comparative fit index (CFI)	> 0.95	0.987	0.749	0.952	0.666	0.877	0.556
Adjusted Goodness-of-fit index (AGFI)	> 0.95	0.958	0.813	0.925	0.764	0.876	0.732
Tucker-Lewis index (TLI)	> 0.95	0.968	0.581	0.899	0.499	0.785	0.409

[a]Dependent variable: score of 10-item Patient Activation Measure; Independent variables: score of 15-item Geriatric Depression Scale and 15-item Summer Heat Adaptation Scale; Covariates: Five-covariate model (number of diseases, level of education, heavy drinking, family history of cardiovascular diseases, age, number of diseases); Four-covariate model (number of diseases, level of education, heavy drinking, family history of cardiovascular diseases; age); Three-covariate model (level of education, heavy drinking, family history of cardiovascular diseases).

age ≥ 85, the scoring scheme for age in the VES-13 [Andrade et al. 2021]) on activation seems to be consistent with the chronographic degeneration of human body functions and the decline in activation over time, which is irreversible or unmanipulable. The diminishing effect of aging on activation thus challenges the adoption of rejuvenation strategies (e.g., reassuming vigorous exercise) to enhance older adults' activation. Interventions blindly incorporating regular practice of moderate physical activity may not be appropriate for much older adults with CVD-related conditions.

Physical frailty, as measured by VES-13, captures age-related vulnerability in association with functional disability for independent living (Andrade et al. 2021). In this study, VES-13 did not exhibit a significant impact on patient activation. In general, the more physically vulnerable a person is, the more physically inactive they are. Our participants were predominantly farmers or peasants who had their own land and made a living mainly by planting and selling crops, vegetables, fruits, poultry or livestock and most were still active in labour work. Such a laborious lifestyle is consistent with the fact that nearly four-fifths of the participants had moderate or high levels of physical activity. High-energy consumption (e.g., prolonged physical activity or exertion at moderate or vigorous levels) under hot weather conditions can aggravate weakened responses in older adults (e.g., reduced perception and down-slowed protective reactions to harmful stimuli), increasing the risk of severe heat-related illness and mortality (Vu et al. 2019; Wang 2018). Although the multiple benefits of physical activity in older adults are widely recognised (Westland et al. 2020), a significant effect of physical activity on activation was not identified in our study. This somewhat echoes the others' findings that activation intervention had little effect on physical activity among adults aged 40–75 at risk for CVDs (Westland et al. 2020). Moreover, it remains difficult to determine whether the amount or intensity of physical activity is beneficial or harmful to older adults. A more accurate measurement of physical activity (e.g., the accelerometer) like the others did among agricultural workers (Mix et al. 2019) should be attempted to capture the variance of physical activity and the resultant activation changes to better help older adults regulate physical activity during hot summer days.

This study also found that being female, obese and hypertensive—risk factors for CVDs and MACEs and contextual factors for self-management (Bauer et al. 2023; The Writing Committee 2022)—was associated with lower activation, although the impact was insignificant. A lower level of activation indicates poorer recognition and self-management of such non-beneficial contextual factors (Hibbard et al. 2004). Healthcare professionals, including nurses, should pay more attention to older female adults with hypertension and/or obesity to enhance their knowledge, skills and confidence in self-managing these conditions (i.e., activation) for better health outcomes.

To our knowledge, this is the first study that reveals a significant association between summer heat adaptation and patient activation in older adults with multiple risk factors for CVDs or MACEs. Accumulated summer heat adaptation resulting from repeated seasonal heat exposure may foster the growth of activation in older labourious farmers to self-manage chronic conditions. The instrument to quantify summer heat adaptation (i.e., SHAS-15) contains items that measure the awareness of and attitudes toward health threats of summer heat in addition to those on heat adaptive behaviours (Wang 2018). However, it remains unclear whether the effect on patient action is primarily because of spontaneous or habitual heat adaptation. More investigations are required to increase the knowledge about the relationship between summer heat adaptation and patient activation for better self-management in the face of increasing extreme heat events, especially among older adults with cognitive impairment or psychological disorders who may lose some of their habitual heat adaptation.

6.1 | Strength and Limitations

This study investigated the effects of depression on activation and summer heat adaptation by considering important factors in rural older adults with an increased risk of CVDs or MACEs during hot summer days. Priority problems (e.g., depression and drinking behaviour) for tailored interventions have been identified to enhance the health of older adults in rural areas. The lack of COVID-19 cases in the study area during the survey period precluded any interpretation of the impact regarding the pandemic.

Data were collected during the hottest summer days, which were well predicted and widely applied in traditional Chinese medicine (e.g., treating asthma in Dog Days to prevent the attack in winter) (Wen et al. 2015). However, we did not examine the linkage between air temperature (e.g., daily maximum temperature informing the occurrence of heatwaves) and patient activation, summer heat adaptation and depression, respectively. This limits the analysis of the exact impact of summer heat on the activity of older adults, along with the other contributory factors. For instance, physical activity varied by age, sex and types of work in the field, informing the design of activation interventions tailored for certain subpopulations who did not reduce overall physical activity even in a dangerously high temperature environment (Mix et al. 2019).

The selection of participants was based on the number of risk factors for CVDs without quantifying the risk (e.g., the risk score). It is difficult to assess the degree to which the risk of CVDs or MACEs influences activation in older adults. Eligible older adults were only those with multiple risk factors for CVDs or MACEs and without severe conditions, as recorded in the study community health center. This study's findings regarding low activation and influencing factors may not apply to the other older populations.

In addition, the actual sample size was greater than what was estimated and the non-response rate was only approximately one-third of the anticipated rate. Therefore, the sample size was considered adequate.

6.2 | Implication for Nursing Practice

It is imperative to raise nurses' awareness about the vulnerability of older adults with multiple risk factors for CVDs or MACEs to extreme heat in the context of global warming and climate

change. With knowledge about the contribution of activation and certain modifiable factors (e.g., depression, heavy drinking and summer heat adaptation) to self-managing chronic conditions for better outcomes, nurses could educate and further empower older adults and/or their caregivers to tackle heat-complicated conditions in any settings when appropriate. Educational programs should be developed and delivered to improve nurses' knowledge, skills and attitudes to fulfil their roles in assisting and supporting patients for better self-management and health outcomes. Given the paucity of evidence, nurses should conduct or participate in more practice-oriented studies, contributing to the advancement of care provision incorporating prevention, mitigation and adaptation strategies to minimise the health impact of heat hazards. Nurses are also expected to play critical roles in advocating and promoting tailored interventions centring activation and heat adaptation for older adults with CVDs or related conditions, desirably addressing concerns about participants' mental health (i.e., depression), unhealthy behaviours (i.e., drinking problem) and education level to improve population health in summer.

6.3 | Recommendations for Future Research

The high prevalence of multimorbidity and behavioural problems (such as drinking, smoking and potentially unhealthy diets causing obesity) in this rural older population with low activation necessitates appropriate preventive interventions to be developed for better health outcomes. Otherwise, the burden on health systems and families of older adults because of poor management of CVD-related risk conditions would increase, given the rapidly aging population nationally and worldwide in recent years.

Despite the inconsistency in others' findings about the effect of depression on activation, this study revealed a salient adverse impact. Considering the positive influences of education, family and multimorbidity, more coordinated strategies should be incorporated into activation and heat adaptation interventions for older adults with CVD-related conditions to also address worrying concerns such as heavy drinking, dieting and smoking problems.

Intensely increasing heat hazards, along with global warming, necessitate effective responses to meet the growing healthcare needs among frail older adults (Romanello et al. 2023). However, there is a scarcity of research on heat adaptation in the most vulnerable people, such as this study sample. Those with cognitive or psychosocial problems may encounter more difficulties in learning and managing their own health problems in the face of extreme heat events (e.g., heatwaves). Early preparation for tackling heat-complicated situations by enhancing activation would be more meaningful as opposed to just teaching heat-adaptive behaviours, which requires careful examination and tailored support in older adults with CVD-related conditions who experience and survive extreme heat hazards.

7 | Conclusion

This study revealed that older adults with an elevated risk of CVDs or MACEs in rural areas had limited ability to confront complicated conditions, making them highly vulnerable to the health threats posed by summer heat. Higher activation was associated with fewer depressive symptoms and greater adaptation to summer heat in older rural populations, influenced by contextual factors such as age, education level, multimorbidity, alcohol consumption and family history of CVDs. Community nurses could play critical roles in advocating and promoting primary care programmes tailored according to individual characteristics (such as their level of education) and addressing multiple concerns (such as drinking problems) that may threaten the health of older adults during hot summer days. Further investigations are needed to enhance nurses' potential in supporting frail older adults in deprived areas, improving their activation and/or summer heat adaptation to address depression and lifestyle problems, particularly alcohol consumption.

Author Contributions

Yuli Zang: conceptualisation, methodology, resources, supervision, project administration, data curation, formal analysis, visualisation, writing – original draft, writing – review and editing. **Lihua Wang:** conceptualisation, methodology, resources, investigation, data curation, validation, writing – original draft, writing – review and editing. **Kai Chow Choi:** methodology, data curation, validation, writing – original draft, writing – review and editing. **Hongxia Du:** conceptualisation, resources, supervision, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.