Cities & Health

ISSN: 2374-8834 (Print) 2374-8842 (Online) Journal homepage: www.tandfonline.com/journals/rcah20

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To cite this article: Jifei Chen, Xiaoming Shi & Laurence L. Delina (13 Jun 2025): Cold spells and mental well-being: the influence of cold spells on older adults in Jinan, China, Cities & Health, DOI: 10.1080/23748834.2025.2513781

To link to this article: https://doi.org/10.1080/23748834.2025.2513781

Published online: 13 Jun 2025.

CITIES & HEALTH
https://doi.org/10.1080/23748834.2025.2513781

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ORIGINAL SCHOLARSHIP

Cold spells and mental well-being: the influence of cold spells on older adults in Jinan, China

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ABSTRACT

Extreme weather events, particularly freezing spells, present significant risks to the mental well-being of vulnerable populations, especially older adults. Despite their heightened susceptibility to such conditions, research examining the impact of cold spells on this demographic remains limited. This study investigates the effects of cold spells on the mental well-being of older adults in Jinan, China, while also assessing the preparedness of community services to meet the challenges posed by these events. We conducted in-depth interviews with 21 older adults, selected based on specific criteria, and employed thematic analysis to interpret the qualitative data. Our findings indicate that cold spells significantly impair the mental well-being of older adults, with participants reporting depression, mood disturbances, disrupted sleep patterns, and heightened social isolation. Furthermore, there is a marked deficiency in effective coping strategies for managing the adverse effects of cold weather. This study highlights the urgent need for action plans, including the development of targeted mental health services and educational campaigns addressing the health impacts of extreme weather on older adults, providing valuable insights for policymakers and healthcare providers in creating interventions for this vulnerable population.

ARTICLE HISTORY
Received 16 December 2024
Accepted 27 May 2025

KEYWORDS
Cold spells; mental well-being; older adults; extreme weather events; China

Introduction

As global warming intensifies, the frequency and severity of extreme weather events are on the rise. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicates that global surface temperatures increased by 1.09 °C from 2011 to 2020 compared to the average from 1850 to 1900, with significant warming observed in the mid-latitudes of the Northern Hemisphere (Masson-Delmotte *et al.* 2021). In China, annual mean surface air temperatures have risen by 1.12 °C since 1901, exceeding the global average (Ren *et al.* 2017). Of particular concern is the increasing frequency and intensity of extreme cold events, which exhibit a notable trend towards more frequent cold spells despite the overarching trend of global warming (Kodra *et al.* 2011).

A cold spell is defined as an extreme weather event characterised by surface air temperatures that are unusually low and persist for several days, significantly below normal levels (Meng *et al.* 2022). Currently, there is no universally accepted definition for cold spells globally, resulting in considerable variation across different studies (Gao *et al.* 2024). The most widely recognised definition categorises cold spells as events that fall below a specific temperature threshold and last for a minimum of two days (Ryti *et al.* 2016). Most research on the health impacts of cold spells has concentrated on physical health rather than mental well-being (Carmona *et al.* 2016, Antunes *et al.* 2017, Martinez-Solanas *et al.* 2019). The Global Burden of Disease data reveals that mortality associated with cold spells is significantly higher than that linked to heat exposure globally (Lei *et al.* 2022). In China, excess deaths attributable to cold are 2.5 times greater than those caused by extreme heat (Xie *et al.* 2024).

Furthermore, while the risk associated with heatwaves has declined in Japan and Korea, the risk from cold spells has increased over time (Lee *et al.* 2018). Health risks from cold exposure significantly elevate the likelihood of morbidity from cardiovascular and kidney diseases, as well as worsen chronic respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD) (Thompson *et al.* 2018, Yu *et al.* 2020). Additionally, extreme cold events facilitate the spread of infectious diseases, particularly increasing mortality risks among older adults and individuals with pre-existing conditions (Lian *et al.* 2024).

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The World Health Organization emphasises that mental well-being is integral to overall health, defining it not merely as the absence of disease but as a state of mental completeness and adaptive thinking (Galderisi *et al.* 2015). Extreme temperatures can evoke negative emotions and elevate the risk of mental disorders (Noelke *et al.* 2016). Research indicates that the relationship between temperature and mental well-being follows an inverted U-shaped pattern (Khan *et al.* 2021, Hua *et al.* 2023), whereby prolonged exposure to extreme temperatures significantly increases the prevalence of mental illness (Niu *et al.* 2020); low temperatures, in particular, can trigger depressive symptoms and potentially lead to suicidal thoughts and behaviours in individuals already suffering from major depression (Prudkov and Rodina 2019, Jiang *et al.* 2022).

While quantitative studies highlight the physiological and psychological effects of cold, qualitative research offers insights into the nuanced subjective experiences and responses to cold stress. For instance, Tabudlo *et al.* (2022) found that cold weather significantly restricts older adults' mobility, resulting in social isolation, reduced activity levels, and heightened emotional distress. Participants reported feelings of demotivation to venture outside and frustration over their inability to maintain their daily routines, which worsened their sense of helplessness. Similarly, Middleton *et al.* (2020) explored Inuit communities and discovered that extreme cold disrupts social connections and daily life, thereby increasing stress and uncertainty. Seasonal weather patterns greatly influence identity and well-being, while unexpected cold events exacerbate emotional distress. Cusack *et al.* (2013) highlighted that cold temperatures further compromise the mental well-being of homeless individuals, amplifying vulnerability, stress, and isolation due to limited access to shelter.

Older adults are particularly vulnerable to extreme temperatures, with the mortality burden associated with temperature-related risk factors increasing progressively with age (Rodrigues *et al.* 2021). By 2050, the number of individuals aged 65 and older is projected to reach 160 million, constituting 17 per cent of the global population (Roberts *et al.* 2018). However, current attention to the needs of this vulnerable group is insufficient (Kınay *et al.* 2021). The Lancet Countdown to 2023 emphasises that discussions surrounding climate change often overlook the older population (Romanello *et al.* 2023). Although studies have examined how temperature affects mental well-being, there is a notable scarcity of empirical research specifically addressing cold spells. Most investigations have focused on the effects of heat on mental health, often overlooking specific groups, particularly older adults within the context of ageing (Ratwatte *et al.* 2022). Therefore, this study aims to examine the impact of cold waves on the mental well-being of older adults in Jinan, a rapidly developing city in China.

This study compares its findings with existing literature on the relationship between ambient temperature, mental well-being, and behavioural responses. The discussion highlights the similarities and differences among these studies, primarily focusing on how cold events impact the mental well-being of older adults. Additionally, we explore the potential mechanisms behind our observations, emphasising how sleep disturbances and reduced mobility significantly link low temperatures to adverse mental well-being outcomes.

Employing a qualitative approach that includes in-depth interviews and thematic analysis, this study seeks to provide a nuanced understanding of the complex relationship between cold spells and the mental well-being of older adults. Previous studies indicate that qualitative methods are particularly effective for exploring individuals' experiences of extreme weather, offering critical insights into social factors and adaptation strategies that quantitative research cannot fully capture (Deglon *et al.* 2023, Kleinberg and Toomey 2023). Furthermore, we investigate both the immediate effects and long-term implications of cold spells on mental well-being, thereby addressing a significant gap in the current research. Consequently, we seek to address the following research questions (RQs): (RQ1) What underlying factors contribute to the heightened vulnerability of older adults during cold spells? (RQ2) How do cold spells affect their activities and mental well-being? and (RQ3) What coping strategies do they use to deal with cold spells?

This paper is organised as follows: Section "Materials and methods: a qualitative study of the lived experiences of older adults in conditions of extreme cold" describes the materials and methods we used in our study and outlines our research approach. Section "Results: understanding the vulnerability of older adults during cold spells" reports the results of our analysis, presenting detailed themes and sub-themes in our findings. In Section "Discussion and implications: exploring vulnerabilities, coping strategies, and community responses to cold weather challenges", we discuss these results. Finally, Section "Conclusion" concludes the paper by summarising the key findings and providing recommendations for future research and practical applications.

Materials and methods: a qualitative study of the lived experiences of older adults in conditions of extreme cold

Study location

This study was conducted in Jinan City, China, which, as of 2023, boasts an approximate permanent population of 9.437 million residents. About 1.837 million individuals are older adults aged 60 and above, representing 19.96 per cent of the total demographic (Jinan Statistical Yearbook 2023). This substantial proportion of older adults underscores the importance of examining their needs and vulnerabilities, particularly in extreme weather events.

The Jinan Meteorological Bureau has reported that global warming, in conjunction with the Pacific El Niño phenomenon, has increased the frequency of extreme cold and heat events in the region during 2023. Notably, on 17 December 2023, the city recorded a historical low temperature of −19.6 °C, establishing a new record for this time of the year (Shandong Provincial Meteorological Bureau 2024). Such extreme temperature fluctuations pose significant risks, particularly to vulnerable populations such as older adults, who may experience heightened susceptibility to the adverse effects of cold spells.

Given these alarming trends, it is imperative to investigate the impact of extreme cold conditions on the mental well-being of older adults residing in urban areas like Jinan. The increased likelihood of cold spells not only exacerbates health risks but also has profound implications for this demographic's psychological and emotional stability.

Methods: qualitative data instrument and collection procedure

Author 1 conducted the interviews in Mandarin from 1 December 2023, to 20 January 2024. Each interview lasted, on average, between 20 and 60 minutes, allowing for in-depth exploration of participants' experiences. This study involved 21 participants whose ages ranged from 60 to 85 years. Data saturation was achieved with this sample size, as significant similarities emerged in their narrative responses, indicating that no new information was being generated. The protocol for this study received ethical approval from the ethics committee of the Hong Kong University of Science and Technology (HREP-2023-0439).

To establish rapport and introduce the research project effectively, Author 1 first contacted community leaders familiar with Jinan's older population. These leaders were provided a guide Author 1 had developed detailing the hazards associated with extreme cold and potential adaptation strategies (see Appendix A). They played a crucial role in identifying participants, facilitating home visits, and recruiting interviewees.

Participants were recruited through purposive sampling based on specific inclusion criteria, which mandated that individuals be (1) aged 60 or older, (2) residing in urban areas, and (3) capable of providing informed consent. This approach aimed to capture diverse experiences through maximum variation sampling. Conversely, individuals suffering from severe illnesses that hindered their ability to cooperate were excluded from the study.

We utilised an iterative semi-structured interview guide, focusing on the impacts of cold waves as identified in existing literature (Liddell and Guiney 2015, Janssen *et al.* 2022, 2023) (refer to Appendix B). To enhance the credibility and reliability of our study, we conducted small-scale pilot testing in Jinan, as recommended by Malmqvist *et al.* (2019) and Gani *et al.* (2020), who underscore the significance of piloting in qualitative research to ensure the clarity and appropriateness of interview questions. This pilot testing involved consulting older participants to evaluate their comprehension and to confirm that the questions were neither leading nor ambiguous.

Prior to the interviews, participants were informed about the study's objectives, and their written consent was obtained. The interviews commenced with discussions about participants' feelings and experiences related to cold waves to create a comfortable atmosphere for dialogue. Subsequently, we posed specific questions regarding the psychological effects of cold waves, including enquiries such as, 'How do cold waves affect your mood?' and 'Which aspects of your daily life are influenced?' To further explore coping strategies, participants were asked, 'What measures do you take to protect yourself from cold waves?' Interview participants received a cotton hat and a water cup as tokens of appreciation. All interviews were audio-recorded, transcribed, and translated into English using iFlyTek (Wang and Tian 2023).

Analytical framework and coding protocol

Our analysis is grounded in the framework outlined in the IPCC Sixth Assessment Report (Portner *et al.* 2022), which examines the relationship between climate change and its impacts on vulnerable populations (see Figure 1). This risk assessment framework elucidates the effects of cold spells on the mental

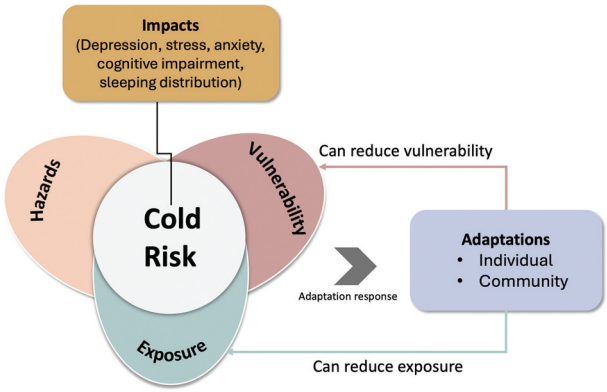

Figure 1. A framework illustrating the effects of cold spells in Jinan City. Source: the Authors.

health of at-risk groups, specifically older adults in Jinan.

In the context of this study, the framework encompasses the following components:

(1) The hazard represents the cold events that directly threaten mental well-being.
(2) Exposure refers to the presence of older adults, their livelihoods, environmental functions, infrastructure, resources, and economic, social, and cultural assets in urban areas that could be adversely affected by cold events.
(3) Vulnerability factors include pre-existing health conditions, occupational risks, and family issues, all of which can exacerbate the psychological and physical effects of cold spells on mental well-being. Such factors increase the vulnerability of certain individuals to the adverse impacts of cold exposure.
(4) The impacts on mental well-being focus on various mental health outcomes, including depression, stress, anxiety, cognitive impairment, and sleep disturbances, as identified in the literature.
(5) Adaptations, both individual and community-based, aim to minimise vulnerability and exposure. Individual adaptations may involve improved insulation and heating systems, whereas community initiatives could include establishing warm centres and providing targeted mental health support. These adaptations are crucial for reducing risks by enhancing resilience and mitigating the impact of cold spells.

We employed a deductive coding approach based on predefined topics from the interview guide as initial codes, complemented by inductive coding to allow for the emergence of new themes from the data (Terry *et al.* 2017). We conducted this thematic analysis using MAXQDA software. As the coding progressed, we reorganised the codes into higher-level categories representing the principal emerging themes corresponding to the three RQs. Subsequently, we developed a codebook that categorised the codes by themes and subthemes, which was continuously updated as new insights were gained.

Results: understanding the vulnerability of older adults during cold spells

Participant demographics

Among the participants, women constituted 62 per cent of the total sample. In terms of marital status, the majority were married, with 14 individuals (67 per cent), while a smaller group consisted of widowed individuals (3 participants or 14 per cent). Most participants lived only with their spouse (16 individuals or 76.2 per cent). In contrast, an equal number resided with their children (2 participants or 9.5 per cent) or in nursing homes (2 participants, also 9.5 per cent). Only one individual (4.8 per cent) lived alone.

The participants exhibited diverse educational backgrounds, with nearly one-third holding tertiary degrees (6 individuals or 29 per cent). In terms of economic status, most participants reported a monthly income ranging from US$ 300 to US$ 900 (12 individuals or 57 per cent). According to the Jinan Statistical Yearbook (Middleton *et al.* 2020), the average monthly disposable income for residents in Jinan was approximately US$ 608 in 2023. Additionally, a significant proportion of the participants were retired, comprising 67 per cent of the sample. For further details on the participants' demographic characteristics, please refer to Table 1.

On RQ1: Factors Increasing Older Adults' Vulnerability to Cold Spells

Deterioration of chronic conditions and mental distress

Participant 12 (age 62) reported that a sudden drop in temperature worsened her incision pain. She felt a piercing cold, noting, 'the incision aches faintly'. A strong link existed between her pain and cold, accompanied by anxiety and discomfort. She added, 'Sharp temperature drops make pain feel like a knot in my heart, prompting fears about the tumour'. Participant 10 (age 61) observed that the

Table 1. Demographic characteristics of the study participants.

Participant code	Age	Gender	Marital Status	Living Arrangements	Education	Income	Employment Status
1	61	Female	Married	Living with spouse only	Tertiary or above	$300-900	Retired
2	68	Female	Widowed	Living with children	Primary or low	<$200	Unemployed
3	69	Female	Married	Living with spouse only	Primary or low	<$200	Retired
4	73	Female	Married	Living with spouse only	Tertiary or above	$1000-above	Retired
5	74	Female	Married	Living with spouse only	Secondary	$300-900	Retired
6	60	Female	Married	Living with spouse only	Secondary	$300-900	Employed
7	64	Female	Married	Living with spouse only	Secondary	$300-900	Employed
8	68	Female	Married	Living with spouse only	Tertiary or above	$1000-above	Retired
9	60	Female	Married	Living with spouse only	Tertiary or above	$300-900	Employed
10	61	Female	Married	Living with spouse only	Primary or low	$300-900	Employed
11	68	Female	Married	Living with spouse only	Primary or low	$300-900	Employed
12	62	Female	Married	Living with spouse only	Tertiary or above	$1000-above	Retired
13	73	Female	Married	Living with spouse only	Primary or low	$300-900	Retired
14	74	Male	Married	Living with spouse only	Primary or low	<$200	Retired
15	76	Male	Single	Nursing home	Primary or low	<$200	Unemployed
16	83	Male	Widowed	Living with children	Tertiary or above	$1000-above	Retired
17	73	Male	Married	Living with spouse only	Primary or low	$300-900	Retired
18	74	Male	Married	Living with spouse only	Secondary	$300-900	Retired
19	63	Male	Widowed	Living alone	Secondary	$300-900	Employed
20	85	Male	Widowed	Nursing home	Primary or low	<$200	Unemployed
21	74	Male	Married	Living with spouse only	Secondary	$300-900	Retired

cold intensified her back pain and irritability, which she likened to 'inner anxiety and unrest,' disrupting her daily activities. She conveyed, 'The impatience is indescribable when my back aches intensely, like a fire in my heart, leaving me restless.'

Participants with chronic conditions, like arthritis, noted that cold weather worsened their discomfort. Participant 18 (age 74) described his legs as 'extremely uncomfortable' in the cold, which limited his daily activities and caused anxiety about his health. Participant 14 (age 74) mentioned that while he is healthy, his wife suffers from lower back pain due to a slipped disc, becoming very sensitive to cold. Their children were provided with heat pads and blankets to ease her pain. He remains resilient, saying, 'I'm healthy; I can usually tough it out'.

Occupation-related risks

Participants showed varied outdoor activity levels during cold spells. Some persisted in their routines due to work obligations. For example, street sweepers found their jobs physically demanding regardless of the weather. One described managing snowy commutes as essential to avoid income loss (Participant 7, Female, Age 64). Another participant 6 (Female, age 60), a security guard, switched to day shifts for better weather coping. She noted, 'It gives me time to rest and care for my husband. The security room has air conditioning, so the weather outside doesn't matter'. This schedule change enhances her ability to rest and support her husband amid adverse conditions outside.

Family dynamics and support

Cold spells intensify older adults' emotional challenges, particularly regarding family relationships and intergenerational dynamics. Participants frequently noted that winter amplifies feelings of loneliness and loss, especially for those separated from loved ones, like distant children or deceased spouses. The physical isolation brought on by the cold mirrors exacerbates emotional distance, creating a complex interplay between environmental conditions and familial connections.

For example, Participant 21 (Male, age 74) shared his heartfelt reflections about missing his son during the winter months, stating, 'I miss my son very much late at night or when the winter wind blows'. He emphasised that since his son moved away, the house feels significantly quieter, and he experiences a profound longing, particularly when the nights are long, or the winds are cold. Similarly, Participant 16 (Male, Age 83) explained how the snowy landscape brings back memories of his late wife, emphasising the loss of warmth within the family following her passing and the challenges posed by his son's work commitments. He expressed, 'Whenever I see the snow falling outside the window, I think of the winters I spent with my wife when she was alive. The house was always warm back then. Now that she is gone, and my son cannot be by my side because of his work, I can only show my longing and care through phone calls. This

inability to see them and provide support makes me feel lonely and desolate during winter'. Overall, the winter environment significantly deepens feelings of isolation for older adults, particularly after the loss of intimate partners and physical separation from family members.

On RQ2: Cold-induced Activity Restrictions and The Impacts of Cold Spells on Mental Well-being

Decreased outdoor participation and social isolation

Participants felt physically constrained by the cold weather, which deterred them from outdoor activities. One 68-year-old female participant noted, 'The wind outside is biting when it gets cold, and after one outing, I have no desire to go out again. I feel surrounded by winter, trapped at home, and unwilling to move'. Similarly, Participant 18 (Male, Age 74) conveyed feelings of entrapment during winter, stating, 'Compared to summer, I feel more depressed and anxious in winter. This reduction in social activities exacerbates my sense of loneliness'. This weather-related discomfort has led to a decline in social engagement, with one 61-year-old female participant (Participant 1) expressing a desire to volunteer but feeling like a burden due to familial concerns over her health.

Participant 2 (Female, Age 68) highlighted her boredom from staying at home during winter, saying, 'Yes, when I stay home, I feel quite bored. I wander around the house, planting flowers and watching TV'. Despite this, she longs for social interaction, stating, 'I still hope for something new, to chat with someone, to alleviate my boredom'. Conversely, Participant 13 (Female, Age 73) remarked on the natural decrease in outdoor activity during colder months, acknowledging, 'Each season has its characteristics, and winter is inherently cold'. Participant 5 (Female, Age 74) described her self-imposed isolation due to health concerns: 'I feel that as I grow older, my immune system is weaker, so I am more likely to catch a cold'. In contrast, her husband braves the cold to socialise, reflecting a common trend among women in her demographic to stay indoors, often caring for grandchildren rather than engaging socially.

Heightened depressive symptoms

Several participants reported that depressive moods intensified during colder weather, significantly impacting their social lives and daily activities while also limiting their ability to engage in enjoyable pursuits. For instance, Participant 9 (Female, Age 60) noted, 'Whenever winter arrives... my pain seems more intolerable. This persistent pain makes me feel helpless and sometimes even very low'. Similarly, Participant 18 (Male, Age 74) mentioned experiencing heightened depression and anxiety during winter: 'Compared to summer, I feel more depressed and anxious... I have become less willing to participate in activities I previously enjoyed'.

Furthermore, Participant 4 (Female, Age 73) expressed sadness when confined indoors, stating, 'Sometimes, I remain at home all day, gazing at the cold wind outside...' In addition, Participant 3 (Female, Age 69) reported mood instability during the cold months: 'Whenever I am in a bad mood, I feel irritable... sometimes even a small thing can make me very angry'. This emotional instability not only disrupted her well-being but also affected her family dynamics, as she acknowledged, 'I know this is a burden for my family... but sometimes the pain makes it impossible for me to control my emotions'.

In contrast, Participant 12 (Female, Age 62) stated that her emotions remained stable; however, discomfort from pain triggered distress. She remarked, 'My mood does not change much, but when it hurts, I feel very uncomfortable'. Despite this challenge, she effectively manages her emotions and strives to understand her husband's perspective, stating, 'I choose not to burden him with my negative feelings'. Additionally, Participant 17 (Male, Age 73) shared that cold weather irritated his wife, but he emphasised the importance of patience: 'I understand how difficult it must be for her... I try to remain calm and patient'. While emotional instability can lead to family tension, these experiences reveal that responses vary based on individual traits and coping strategies, with some struggling to control their emotions. In contrast, others manage their reactions with understanding.

Cognitive function alterations

Participants expressed concern over declining memory in colder temperatures. Participant 6 (Female, Age 60) said, 'My memory has become terrible; I forget things quickly. The cold makes my body stiff and my mind foggy. Sometimes, I forget to take out the trash in an instant'. Participant 1 (Female, Age 61) worried about feeling less intelligent due to memory lapses, stating, 'When it's cold, I head to the kitchen, but I forget what I need by the time I arrive. The chill makes me anxious, making me suspect I have Alzheimer's'.

Research suggests cold stress may impair cognitive performance (Spitznagel *et al.* 2009, Muller *et al.* 2012). Participant 5 (Female, Age 74) noted she often

misplaces items, spending long periods searching for them, especially in cold weather. She commented, 'I forget where I put something as soon as I set it down, which happens more in winter'. Participants also reported difficulty concentrating due to distractions. Participant 19 (Male, Age 63) described a decline in attention span: 'When it's colder, no one goes out, and everything feels lifeless. I try to read but struggle to concentrate; it feels heavy'.

Sleep disturbances and mood consequences

Participants reported that lower temperatures harmed their sleep. For example, Participant 10 (Female, 61) said her 'sleep quality has declined' as she needs time to 'warm up in bed'. She also noted that she wakes up quickly due to slight noises or feeling cold. Additionally, cold air caused significant discomfort and sleep issues. Participant 3 (Female, 69) shared that the 'cold air penetrated my skin, causing poor circulation and discomfort that interrupted my sleep'.

Psychological factors, especially anxiety and overthinking, further worsened sleep problems in cold weather. Participants reported increased nighttime activity, leading to insomnia. For instance, Participant 8 (68) stated that her 'thoughts run wild at night'. Similarly, Participant 10 mentioned she 'sleeps less and wakes up very early during cold weather'.

On RQ3: Coping Strategies of Older Adults During Cold Spells

Indoor adaptations

Older adults use four main strategies to cope with cold: indoor adjustments, outdoor adjustments, weather monitoring, and community support. These include warmth and emotional coping measures, influenced by centralised heating in northern China. Older people increasingly use AI devices and stay indoors during harsh weather.

While at home, older adults manage warmth through various means. Many rely on central heating and personal comfort measures. For example, Participant 18 (Male, 74) stays warm by wearing thick socks and blankets while watching TV. Additionally, homes often have underfloor heating systems. Participant 15 (Male, 76) explained, 'We keep the floor heat above 18 °C to stay warm' Many also use electric blankets, like Participant 4 (Female, 73), who says, 'Turning on the blanket keeps me warm all night'.

Thus, they effectively combine heating systems and personal techniques. However, socioeconomic factors affect these adaptations significantly. Limited finances reduce some older adults' ability to heat their homes. Participant 2 (Female, 68), from a community without central heating, stated, 'I turn off the AC to save electricity. I can't afford it since my son supports me. You young people don't understand – running the AC in winter is expensive'.

Outdoor adaptations

Older adults venture outside in cold weather and take various precautions to stay warm. In particular, many wear layers of clothing, including scarves, hats, and gloves, to protect themselves from the chill. For example, Participant 16 (Male aged 83) noted that he takes great care in choosing his warming gear based on the weather conditions. Likewise, Participant 17, a 73-year-old male, shared: 'I dress warmly when I go outside, with wool hats and scarves. Yesterday, I only wore one pair of gloves, and my hands were freezing. Today, I wore two pairs'. Furthermore, older adults generally opt for warm items. In this regard, Participant 14 (Male aged 74) mentioned: 'I bundle up in a wool sweater, thick coat, hat, and gloves to block the cold wind whenever I leave the house'.

Weather monitoring

Older adults prioritise checking the weather forecast daily to prepare for extreme weather conditions. They access weather information through various devices, including smartphones, televisions, and smart home assistants like the 'Tmall Genie'. The Tmall Genie, a smart speaker and virtual assistant developed by Alibaba Group, integrates multiple functions, including voice-controlled music playback, smart home device management, daily information queries, and voice interaction services. For example, Participant 2 (Female, Age 68) mentions, 'I have a Tmall Genie at home. I ask it about the weather every morning, and it tells me. It is convenient'. Conversely, others, like Participant 10 (Female, Age 61), prefer to check 'the weather on my phone, while the community also sends us notices about preparing for rain or hail'.

Keeping track of the weather is essential for older adults, especially when planning their daily activities. Participant 8 (Female, Age 68) utilises multiple channels to stay informed and prepare for her plans, stating, 'I follow the weather closely on my phone and TV, especially now that I have daily classes. Knowing what the weather is like is essential'. Therefore, these technological tools help them manage their activities and avoid potentially risky situations. Furthermore, weather warnings hold significant importance in

northern regions for older adults due to the increased risk of sudden and icy weather.

Strategic reduction of outdoor activities

Staying indoors during freezing weather is a crucial adaptation strategy many older adults adopt to prioritise comfort and warmth. Several interviewees highlighted their conscious decision to remain home when temperatures significantly drop. For instance, Participant 13 (Female, Age 73) states, 'If the weather is too cold, I prefer just to stay home', while Participant 3 (Female, Age 69) adds, 'Usually if the forecast says it will be freezing, I stay home and not go out'. This trend underscores a significant behavioural adaptation among older adults, who often rely on weather forecasts to inform their decisions about outdoor activities.

Beyond simply avoiding the outdoors, older adults implement additional measures to keep warm at home. Participant 10 (Female, Age 61) explains, 'I try not to go out and stay warm at home. As for other measures, there is nothing special; wear more clothes and drink hot tea to warm your body'. This practical approach illustrates how they manage their comfort levels during cold weather.

Moreover, for many older adults, venturing outside in winter becomes a genuine inconvenience. Participant 19 (Male, Age 63) expresses this sentiment: 'It is inconvenient to go out in winter, especially for older people. We do not want to go out even more'. This reluctance further emphasises their preference for staying indoors, reinforcing the importance of adaptation strategies prioritising safety and comfort during extreme cold.

Community support

The needs of older adults for community support remain primarily unmet, with many expressing a desire for more social activity spaces, such as areas to play cards. Current facilities often fall short, as many are underutilised or poorly maintained. For instance, Participant 13 (Female, Age 73) laments, 'Our community does not have any activity rooms'. In contrast, Participant 3 (Female, Age 69) notes that the community activity and chess rooms no longer operate as they used to. Additionally, while community staff regularly check on older adults, these interactions often feel formal and lack genuine care, creating communication barriers. As Participant 5 (Female, Age 74) explains, 'There is always a barrier between the community and us residents', leading many to hesitate in voicing their true needs.

Moreover, older adults desire more regular health consultations and workshops on topics like climate change to enhance their knowledge and well-being (Participant 10). However, current health initiatives primarily focus on physical health, neglecting mental well-being. Participant 5 (Female, Age 74) contrasts her community's services with those of Sunshine Community, which used to prioritise emotional well-being. Participants also emphasised the need for improved leisure facilities, fitness equipment designed for older adults, and regular inspections of heating facilities for safety during winter (Participant 2). As Participant 19 (Male, Age 63) suggests, 'Adding more indoor activity spaces can help facilitate communication among older adults'.

Discussion and implications: exploring vulnerabilities, coping strategies, and community responses to cold weather challenges

Impact of cold spells on the mental well-being of older adults

Our main findings indicate that older adults' mental well-being is significantly affected during cold snaps, with mood-related issues such as anxiety and depression being particularly prevalent. These results align with existing literature (Brazienė *et al.* 2022, Janssen *et al.* 2023, Bai and Jin 2023) but highlight a critical gap in mental well-being research. While the impact of cold events on physical health is frequently discussed, the implications for mental well-being – particularly those related to anxiety, depression, and social isolation – have not been sufficiently considered in the context of cold spells. In contrast to previous studies that primarily focus on physical health outcomes, our findings underscore the importance of considering mental well-being during cold events.

Although our analysis primarily focused on China, the relationship between cold weather and threats to mental well-being is evident globally. While climate change has garnered attention for its role in morbidity and mortality associated with overheating (Ma *et al.* 2015, Li *et al.* 2017, Yin *et al.* 2018), our findings indicate that cold conditions can also pose significant health risks. Consequently, we build upon existing research highlighting the connection between long-term temperature fluctuations and depressive symptoms

in middle-aged and older adults (Jin *et al.* 2023). Our analysis demonstrates that the adverse effects of cold temperatures on mental well-being are particularly significant among vulnerable groups, such as older adults. These findings align with other studies suggesting that the impact of freezing temperatures on mental disorders may be more severe than that of high temperatures (Zhang *et al.* 2020).

Our findings reveal that cold events can negatively impact mental well-being, although quantitative studies provide varying results. For example, some studies have reported no significant relationship between low temperatures and self-reported mental well-being outcomes (Obradovich *et al.* 2018), while others suggest that lower temperatures may have beneficial effects on mental health (e.g. Burke *et al.* 2018, Mullins and White 2019, Chen and Yuan 2024). These seemingly contradictory findings underscore the complexity of the connection between temperature and mental well-being, suggesting that effects may be minimised within an 'optimal temperature range', while extreme temperatures – either excessively high or low – can significantly detriment mental well-being.

Research on the relationship between cold temperatures and age-related cognitive decline in older adults presents mixed findings. As individuals age, they often face various sensory impairments, including declines in vision, hearing, and touch (Rotenberg and Dawson 2022). While cognitive changes are anticipated, our results indicate that cold spells can exacerbate these changes, particularly impacting memory, attention, and overall cognitive performance. Some studies have linked extreme cold temperatures to decreased cognitive performance among older adults, reinforcing the notion that cold spells may contribute to cognitive decline (Finlay *et al.* 2019, Khan *et al.* 2021, Hou and Xu 2023). In addition to cognitive impacts, cold temperatures also cause older adults to spend more time indoors, increasing isolation and further affecting cognitive function, simulating previous work (Yu *et al.* 2020).

Our findings also indicated that cold spells significantly alter the behaviour of older adults, primarily by reducing outdoor activities and social interactions. This observation aligns with existing literature and suggests that cold weather decreases outdoor activities and disrupts daily routines, contributing to feelings of isolation. For instance, Hjorthol (2013) found that cold weather reduced shopping trips and visits to friends and family among older adults, while Nakashima *et al.* (2019) noted a decrease in gardening activities during winter. Our study reveals that cold weather decreases outdoor activities and disrupts daily routines, contrasting with Goodwin *et al.* (2000), who reported no significant differences in outdoor activity between winter and summer.

Factors influencing vulnerability and coping strategies among older adults during cold spells

Our study corroborates existing quantitative research demonstrating that older adults in Jinan (Li *et al.* 2016, 2017, Liu *et al.* 2019) with pre-existing chronic illnesses and low incomes face a heightened risk of experiencing the adverse impacts of extreme weather. Age-related differences in vulnerability were noted, with participants like Participant 16 (aged 83) and Participant 20 (aged 85) appearing more adversely affected by cold weather. This finding aligns with Qiu *et al.* (2016), which suggests that the adverse effects of cold on mental well-being increase with age. Additionally, pre-existing chronic illnesses significantly influenced susceptibility to cold weather, consistent with findings that individuals with chronic health issues face greater risks during cold spells (Cotter *et al.* 2012).

Employment status is crucial in shaping how older adults cope with extreme weather. Our study found that working participants (e.g. Participants 6, 7, 9, 10, and 11) experienced additional stress, while retired participants enjoyed greater time flexibility. This finding aligns with Connon and Hall (2021), which suggested that retirement status can affect older adults' ability to adapt to weather extremes. However, some retired participants reported boredom and loneliness during winter months. Qureshi (2023) noted that factors contributing to depression in retirees include reduced social contact, diminished social status, and decreased income. A meta-analysis found that retirement is often linked to increased depressive symptoms, with both involuntary and voluntary retirement heightening the likelihood of depression compared to normal retirement (Li *et al.* 2021). However, studies on retirement's impact on older adults' mental well-being yield inconsistent results; while Fang and Shi (2022) suggests that retirement may improve self-assessed health and reduce depressive symptoms, other studies indicate the opposite. The complexity of retirement's effects on mental well-being can vary based on individual circumstances, retirement type, and the availability of social support.

While education level is not regarded as a direct factor influencing cold vulnerability, it significantly influences older adults' coping strategies during extreme weather events. Participants with higher levels

of education (such as Participants 1, 4, 8, 9, and 12) were better equipped to adopt effective coping strategies. For instance, Participant 8 noted that they closely monitor the weather through their mobile phone and television. This observation aligns with Slack *et al.* (2014), which found that education is linked to improved health literacy and coping strategies. This finding highlights the importance of enhancing health education and access to information for older adults.

Mitigation strategies for cold spells: individual and community responses

Participants proposed various solutions to mitigate the impacts of cold spells, including adequate indoor heating measures, such as wearing thermal clothing and using electric blankets (Jiang *et al.* 2020) and expanding community activity centres and health counselling services (Danielsen *et al.* 2021). Such initiatives would facilitate social interaction and ensure access to vital health information and resources. Participants also expressed a desire for more workshops addressing common health issues among older adults (Aruta 2023), which can empower seniors to manage their health better during cold spells better.

In terms of infrastructure, participants recommended the regular enhancement and maintenance of community heating facilities. This suggestion aligns with the findings of Daniel *et al.* (2021), which highlight the importance of improving housing conditions to reduce cold-related mortality. By investing in robust and efficient heating systems, communities can significantly improve the well-being of older adults during cold spells.

Conclusion

Summary of findings

This qualitative study identifies several underlying factors that contribute to the heightened vulnerability of older adults during cold spells (RQ1). Participants with chronic illnesses, low incomes, and lower levels of education reported a greater susceptibility to mental health issues such as anxiety and depression during cold weather. These vulnerability factors exacerbate their risk and hinder their ability to cope effectively with freezing conditions. Additionally, the study revealed that older adults living alone or lacking social support are particularly at risk, as they experience increased feelings of isolation and loneliness during colder months.

Cold spells significantly impact the activities and mental well-being of older adults (RQ2). Participants reported that their emotional states were adversely affected during cold spells, with many experiencing mood-related issues such as anxiety and depression. The harsh weather conditions reduced outdoor activities and social interactions, further contributing to feelings of isolation. Many expressed concerns about cognitive decline, noting difficulties with memory, attention, and overall cognitive performance during colder periods. This aligns with existing literature that highlights the adverse effects of cold weather on mental health, particularly among vulnerable populations.

Older adults employed various coping strategies in response to the challenges posed by cold spells (RQ3). Participants emphasised the importance of adequate indoor heating and thermal clothing to maintain comfort. Many also sought to engage in indoor activities to mitigate feelings of isolation, such as participating in community centres or accessing mental health counselling services. The study highlighted a strong demand for enhanced community resources, including warm public activity areas and regular mental health support, as essential coping mechanisms. These strategies reflect the need for individual and community-based approaches to effectively support older adults during cold spells.

Limitations and opportunities for future research

This study acknowledges several limitations that may affect the interpretation of the results. Firstly, the small sample size, drawn primarily from a limited number of communities in the central district of Jinan, may not fully represent the diverse experiences of older adults. Future research could explore how the experiences of older adults during cold spells vary across different regions of Jinan and other cities. Combining qualitative interviews with a larger quantitative survey, a mixed-methods approach could provide deeper insights.

Secondly, the initial interviews were conducted to answer different research questions. Therefore, although this study collected important demographic and socioeconomic data, the interviews lacked targeted questions to investigate how intersecting socioeconomic factors and their compounded consequences impact older adults' mental well-being. Future studies should develop interview frameworks that explicitly examine these intersections to better understand how social and structural factors influence mental well-being during extreme weather events.

Moreover, the gender imbalance, with more female participants, raises the question: How do men and women differ in their responses to cold spells? Future studies should aim for a balanced gender representation to enable meaningful comparisons, possibly using surveys designed to capture gender-specific experiences.

Additionally, the study did not examine how different employment types influence access to resources for coping with cold weather, prompting the question: What role does employment status play in shaping vulnerability to cold spells? Future research could involve interviews with participants from various occupational backgrounds to assess the impact of job-related factors.

The reliance on community volunteers for recruitment may have introduced bias, leading to the question: How can researchers ensure that vulnerable populations are adequately represented? Targeted recruitment strategies, such as partnering with healthcare providers, could help reach underrepresented groups.

Finally, self-reported data may introduce recall bias, prompting the question: How can the reliability of self-reported data be enhanced? Longitudinal designs could allow for more accurate mental health assessments and coping strategies during varying weather conditions. Addressing these limitations and exploring these questions will strengthen understanding of cold spells' impacts on older adults and inform effective interventions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The study described in this paper was funded by a grant from the Hong Kong Research Grants Council for the project titled "Energy insecurity in Hong Kong's vulnerable populations" [Project No. 16601022].

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Availability of data and materials

Data is available on request.

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Appendices

Appendix A. A guide to help community residents cope with cold spells developed by Author 1

Appendix B. In-depth interview guide

(1) Climate cognition
- How have you come to understand climate change, and what are your personal observations or impressions about the changes in weather patterns you have experienced?

(2) Physical health
- What kinds of physical sensations and changes in health symptoms do you experience as the weather turns colder?

(3) Emotional response
- In what ways do you find that cold weather affects your mood and emotions?
- What kinds of weather conditions trigger feeling of anxiety?
- What strategies do you use to cope with changes in your emotions due to weather?

(4) Cognition
- Have you observed any differences in your cognitive functions, such as attention, during colder months compared to warmer periods?
- What are your thoughts about this phase of life and any emotions you might be experiencing?
- How does the winter season make you more aware of your age and identify as an older person, and what are your thoughts about this?
- Without referring to anything specific, what are your contemplations about the future and its meaning during winter months?

(5) Memory
- How does the cold weather impact your memory. And are there particular instances that exemplify these effects?

(6) Hobbies
- What hobbies do you pursue during the winter, and how do they adapt to the changing seasons?

(7) Social interactions
- How do you maintain social connections with friends and family throughout the winter season, and could you share how your social interactions adapt to cold?

(8) Daily routine@
- What kind of adjustments do you make to your daily routine in response to the winter season, such as changes to your sleeping patterns or other daily activities?

(9) Adaptations
- How do you ensure you stay warm inside your home during the winter?
- What measures do you take to protect yourself when venturing outside in cold weather?
- How do you stay informed about the weather, and what sources do you rely on for weather forecasting?

(10) Community
- What types of infrastructure or resources are available in your community to assist in coping with the cold and promoting the health of the older adults?
- If you could make recommendations to improve community support, what types of facilities or programs would you suggest boosting the psychological well-being of older adults?