Community-based heat adaptation interventions for improving heat literacy, behaviours, and health outcomes: a systematic review

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Anthropogenic climate change, resulting in a continuous rise of global temperature, has detrimental effects on human health, particularly among vulnerable populations, such as individuals with low income, older adults, and people with pre-existing health conditions. To reduce the heat-related health consequences, effective interventions targeting community members, especially vulnerable populations, are paramount. This systematic review aims to identify and evaluate the effectiveness of community-based heat adaptation behavioural interventions aimed at improving heat literacy, promoting adaptive behaviours, and enhancing health outcomes amid rising global temperatures. In this systematic review, peer-reviewed English-language articles focused on community-based heat adaptation intervention studies published in PubMed, MEDLINE via Ovid, Embase, CINAHL, Scopus, and Web of Science from database inception to Jan 1, 2024, were retrieved and reported according to the PRISMA 2020 guidelines. The quality of the articles was evaluated with the use of a mixed-methods appraisal tool. The analysis synthesised intervention effectiveness across multiple outcome domains measurable at both individual and household levels, identified key factors influencing successful implementation, and highlighted areas for future research. The initial search yielded 1266 articles, of which ten were finally included. The majority of the included studies (n=7) were from high-income countries. Most intervention modules focused on preventive measures during heat exposure, whereas only a few addressed information on disease mechanisms, risk factors, and monitoring environmental changes. Although most studies reported significant improvements in heat literacy and a reduction in heat-related symptoms, the evidence for behavioural changes and health outcomes was mixed. Our review reveals methodological shortcomings, as none of the included studies incorporated heat literacy frameworks, behavioural theory, or participatory approaches to include community input throughout the research. Our findings highlight the need for a comprehensive approach that incorporates frameworks to enhance intervention effectiveness and improve public health resilience amid rising global temperatures. Culturally appropriate community-led interventions and integration of digital tools are promising avenues for increasing uptake of interventions. This study is registered with PROSPERO (CRD42024514188).

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Introduction

Research has shown a substantial association between elevated temperatures and adverse health outcomes, with a 1°C temperature increase correlating with an 18% rise in morbidity and a 35% increase in mortality.[1,2] Mortality risk associated with heat was much higher among rural populations, particularly in low-income and middle-income countries (LMICs), compared with populations in high-income countries (HICs). This difference can be attributed to low adaptive capacity, low socioeconomic status, insufficient infrastructure, increased vulnerability, and the burden on health systems in low-income countries.[3] Exposure to high ambient temperature might lead to physiological changes, such as elevated core body temperature and heart rate, dehydration, decreased volume of bodily fluids, activation of sympathetic nervous system, leukocyte and endothelial cell activation, and hypercoagulability.[4] These physiological changes will further put vulnerable subgroups at risk of heat-related illnesses (eg, older adults, particularly those with cognitive decline, infants, children, pregnant women, individuals with comorbidities, and populations of low socioeconomic status). Individuals who are unable to adapt to sudden changes imposed by environmental heat stress can be especially affected.[4]

To mitigate the health effects of extreme heat, WHO and UN agencies recommend structural measures, such as cool roofs, green buildings, and green spaces, alongside public health strategies that include developing heat action plans, alert protocols, enhancing surveillance systems for heat-related morbidity and mortality, upgrading emergency response plans for health facilities, and organising educational campaigns to promote heat behavioural adaptation.[5] Most intervention measures have focused on population-level heat action plans,[6] with little attention to individual and household levels.[7,8] Heat adaptation initiatives should be developed from a community-based local perspective,[9] recognising that the geographical, climatic, cultural, and socioeconomic characteristics of each area substantially influence its adaptation strategies.[10] Therefore, community-based research offers a framework for equitable involvement of community members, researchers, and stakeholders,[11] enabling them to collaborate on community-identified needs and explore meaningful and practical solutions.[12] As part of this approach, community-led research refers

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to initiatives that are driven by community members who actively identify their needs and participate in the research process, utilising their local knowledge to propose solutions.[13] Consequently, community-based heat adaptation (CBHA) is crucial, as it unites community members, researchers, and stakeholders in specific geographical areas to develop localised strategies for mitigating the health effects of extreme heat. Thereby, CBHA empowers communities to prepare for and cope with heat challenges and enhances overall community resilience.[14] Nevertheless, evidence on the effectiveness of community-based interventions remains insufficient.[6,7,15] Additionally, heat awareness might not necessarily translate into adaptive behaviour, primarily due to factors including low perceived vulnerability, insufficient knowledge on appropriate actions,[15] and the fact that vulnerable groups including older adults and people experiencing homelessness are often inadequately reached by such efforts.[16]

Research underscores the heightened vulnerability of groups with low socioeconomic status to extreme heat due to inadequate housing, restricted access to health care, and insufficient cooling infrastructures.[17] Community-based interventions that focus on heat literacy through promoting accessible strategies, such as weather monitoring, recognising heat-related symptoms and risk factors, and using low-cost and accessible personal cooling techniques, represent a promising avenue to empower individuals and mitigate the adverse health effects of extreme heat.[17] Weather monitoring, as part of heat warning alerts, has shown promising findings in reducing heat-related mortality risk, particularly in vulnerable communities.[18] Preliminary findings from an educational intervention promoting personal cooling strategies indicate improved knowledge and practices during extreme heat exposure, which has led to a reduction in hospital visits among low-income urban communities.[19] Therefore, intervention measures aimed at increasing heat literacy can be effective even in low-income settings with high environmental vulnerability. However, further research is needed to identify effective instructional and delivery methods that ensure the successful uptake of interventions among target populations.

See **Online** for appendix

Previous heat action plans have included heat warning communication campaigns,[20,21] resource distributions (eg, providing fans, water, or air conditioning units to populations at risk),[7,22] home visits to older individuals,[16] and active surveillance programmes.[21,23] However, conclusive evidence on the effectiveness of previous interventions remains insufficient.[6] Nevertheless, these efforts differ from community-based interventions, as previous initiatives (eg, heat action plans, and heat alert and response systems) were generally top down, and led by local governments or health authorities, with little to no input from community members. Furthermore, heat action plans often require substantial financial investments, making their implementation possibly unfeasible in low-resource settings. Therefore, to reduce health risks from rising temperatures, it is essential to implement not only population-level heat action plans but also community-based adaptation strategies that promote community empowerment and drive individual behavioural change through improved heat literacy.

To address the need for effective community-based interventions that enhance heat literacy, behavioural adaptation, and health outcomes, this systematic review aims to: identify and evaluate CBHA behavioural interventions; analyse the types, contents, and delivery strategies of these interventions; assess the effectiveness of strategies in improving heat literacy, behavioural adaptation, quality of life, and health outcomes at the individual level; and identify research gaps to guide future development and implementation of such interventions.

Methods

Search strategy and selection criteria

This systematic review was done according to the PRISMA 2020 guidelines. We reviewed published articles related to intervention studies that tested strategies for adapting to heatwaves or hot weather in a community setting. We searched the PubMed, MEDLINE via Ovid, Embase, CINAHL, Scopus, and Web of Science databases for relevant studies published from the earliest available date up to Jan 1, 2024. The search strategy included medical subject headings, subject headings, and free-text terms related to "heat", "literacy", "intervention", "behavioural adaptation", and "community", combined with outcome measures such as "literacy", "behavioural change", "quality of life", "biomarker", and "health", as detailed in the appendix (pp 1–12). The specific outcome definitions are provided in the appendix (p 13). The search was restricted to publications in English and focused on keywords, titles, and abstracts. Additional studies were identified by hand-searching reference lists of relevant reviews.

Inclusion criteria were peer-reviewed. Articles in English focused on CBHA behavioural intervention studies (see appendix [p 13] for inclusion criteria). We included empirical studies using quantitative, qualitative, or mixed-method approaches. We focused only on behavioural interventions applicable at the individual and household levels. Exclusion criteria included studies that did not test an intervention, publications in languages other than English, studies targeting specific groups (eg, working population or athletes), reviews, grey literature, e-books, book chapters, non-peer-reviewed reports, conference proceedings, letters to editors, and studies reporting only structural interventions (eg, passive cooling or green buildings) or using heat-health action plans (eg, warning and surveillance systems). Search records were compiled using Zotero (version 6) reference management software and transferred to Rayyan, a web-based platform for systematic reviews.

Data analysis

Quality appraisal of the included studies was done with the use of the mixed-method appraisal tool (MMAT), which is designed to assess the methodological rigour of various study designs, particularly interventional studies.[24] The MMAT includes two screening questions and 25 criteria applicable to various study designs. Each study was assigned a total score out of five, with higher scores indicating greater methodological quality.

Two independent researchers (HJ and FIA) initially screened titles and abstracts, excluding studies only when both agreed they did not meet eligibility criteria. Full-text articles of remaining citations were retrieved and assessed for inclusion by both reviewers (HJ and FIA). The reviewers (HJ and FIA) extracted data from each study and evaluated the completeness of the data for extraction. The extracted datapoints included author, title, year of publication, country and setting, study design, study objective, sample size, demographic characteristics of study participants, description of intervention, including intervention types and design, educational materials (content), mode of intervention delivery, duration of intervention, study outcomes, value or significance of findings that reported effectiveness, risk of bias, and strengths and limitations of each study. Disagreements were resolved by consensus or by involving an additional reviewer (TTS). The results were then discussed with all coauthors during project meetings. The multidisciplinary team of this study consisted of authors in the field of climate change (YG, KL, and SB), global public health (FIA, NKJ, TB, TTS, and HJ), internal medicine (GRLR), environmental risk (YG, NM, and TAZ), digital health (JW), environmental monitoring (DG), and health economics (KKCL). The protocol for this systematic review is registered with PROSPERO, CRD42024514188.

Results

A total of 1266 articles were identified, comprising 1243 articles retrieved from database searches and an additional 23 records obtained through hand searches. Duplicates (n=168) were removed, leaving 1075 articles. After screening titles and abstracts, 151 articles were retrieved for further assessment. A further 141 articles were excluded for reasons such as non-relevant publication type (n=6), unrelated topics (n=75), wrong study design (modelling study, heat warning, or non-intervention studies; n=42), and non-related study population (n=18; appendix pp 15–18). Finally, ten studies were chosen to be included in the systematic review. The study selection processes are summarised in the PRISMA flow diagram in figure 1. The quality appraisal revealed that two articles had an MMAT score of 5, seven articles obtained scores of 3 and 4, and one study had a low score of 2 (appendix p 19). All studies clearly stated the objectives with a defined sample population to answer the research questions; however, some studies did not provide details on the sample size and selection criteria (figure 1). The annual growth of publications based on the retrieved search results on the CBHA and health (n=1075) was low before the year 2000, but showed a steep increase after 2010, reaching its highest peak in 2023. The growth in number of publications was compared with the included CBHA studies (n=10) is shown in figure 2.

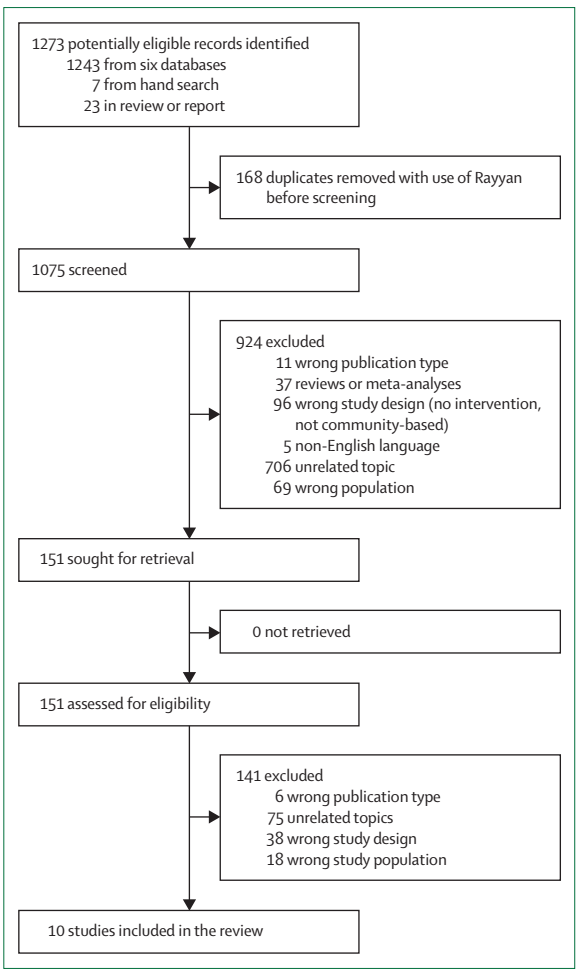

Figure 1: **PRISMA flow diagram**

Table 1 summarises the community-based intervention studies that were identified to improve heat literacy, behavioural heat adaptation strategies, and health outcomes. Of the ten included articles, most (n=7) were based in HICs (Australia, Japan, Canada, Italy, and the USA), whereas only three studies were based in LMICs (China and Pakistan), as depicted in figure 3. The included studies had various designs. Most studies included both men and women, except two that had a higher number of women[25,33] and included older adults.[25–29] Seven studies had large sample sizes and three had fewer than 500 participants (figure 3).[25,32,33]

Table 2 describes the types, contents, and delivery strategies of each intervention. The duration of

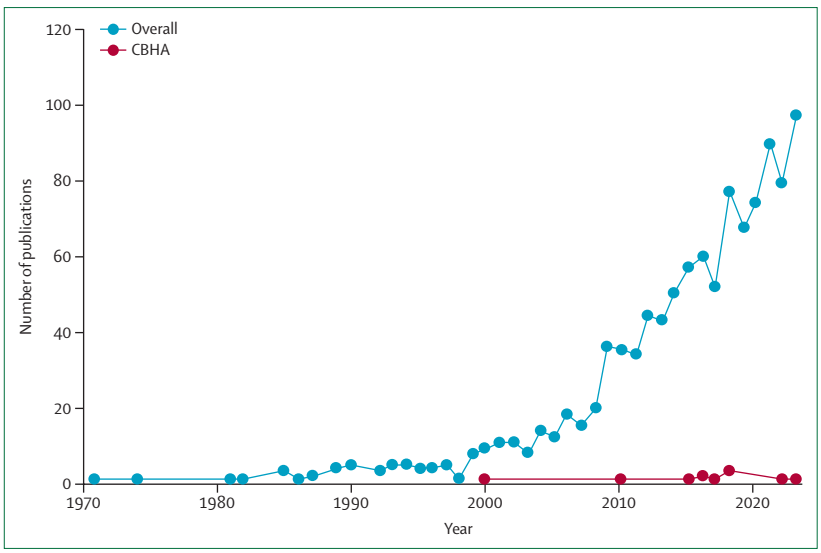

Figure 2: **Annual changes in number of publications**
CBHA=community-based heat adaptation.

interventions ranged from 9 weeks up to 4 months, with a frequency of one to four sessions per participant throughout the intervention phase. Modules covered topics such as monitoring indoor temperature,[25,26] recognising heat-related illness,[19,25,31,32] identifying risk factors,[19] preventive practices,[19,26,27,31,32] and age-specific strategies for older adults.[26,27,29] Five studies combined at least two different topics,[19,25,27,32,33] with the CBHA by Razzak and colleagues[19] offering the most comprehensive modules.

The interventions were delivered in community settings with the use of various methods: written media (posters,[32] brochures, leaflets or fact sheets,[25,29,32] manuals,[33] newspapers,[26] booklets, laminated cards, and fridge magnets[29]); digital media (eg, DVD videos[25] and instant messaging apps[26,30]); individualised[25,28] or automated telephone calls;[27] radio and television programmes;[32] and face-to-face communication, either in groups or individually.[25,31] Two trials[25,31] in Japan provided hands-on interventions for older participants to measure the wet bulb globe temperature at home and raise awareness about heat disorders,[25] whereas another study[31] distributed water bottles with heat prevention messages. A study among communities of low socioeconomic status in urban in Pakistan used customised messages delivered by community health workers.[19]

Some interventions involved multisectoral cooperation and used diverse communication methods. For instance, The Heat Wave Intervention Programme in Licheng, China, used a three-level health-care network involving district, street, and community services, with 24/7 hotlines, WeChat communication, and physicians sharing heat-mitigating information.[26,30] Additionally, the local government in Licheng district provided subsidies to workers during periods of high temperature, enabling them to adjust their work hours according to the daily peak temperature.[26,30] A pilot project in Montreal, QC, Canada, used automated calls to warn about high temperatures and provide protection tips to residents.[27] In Italy, Tips for Hot Weather campaigns were part of the Long Live the Elderly programme.[28] In the USA, one study[33] distributed fridge magnets, information sheets, thermometers, and personalised health education sessions for older participants.

The included studies were done at the community level, enabling outcome evaluation at the individual and household levels, thereby better establishing causal relationships between the interventions and their effectiveness within the communities. The shortest intervention evaluation period was 1·5 months post-intervention, whereas the longest was 1 year after the intervention. Outcomes assessed included heat literacy (n=6), behavioural adaptation (n=7), health outcomes (n=8), and cost-effectiveness (n=1; table 1). We found that CBHA behavioural interventions substantially improved heat literacy, although the results varied among vulnerable groups. Moreover, findings regarding the effects of these interventions on behavioural adaptation and health-related outcomes were mixed.

Six studies[19,25,26,31–33] evaluated the effectiveness of interventions in improving heat literacy, focusing on recognition of heat-related illness, symptoms, and preventive measures. Most studies showed a significant improvement in knowledge levels in the intervention group compared with control groups,[19,25,26,32,33] except one study.[31] Findings from a study in Australia showed that the intervention group had higher heat risk awareness (96%), symptom recognition (78%),[32] and preventive measures knowledge compared with the control group (94·4% *vs* 88·3%, p<0·05).[29] In China, Xu and colleagues[26] found a significant improvement in knowledge (ß=0·387, p<0·001) and attitude (ß=0·166, p<0·01) regarding heat-related effects and preventive measures after the intervention. Meanwhile, a community health worker-led study in Pakistan reported increased awareness of heat illness symptoms (eg, high temperature odds ratio [OR] 2·37), weakness (OR 1·72), mental status [OR=1·88], and tachycardia (OR 1·31),[19] but reduced acknowledgment (OR<1) of outdoor work as a risk factor (OR 0·47) and some immediate actions (eg, calling a helpline [OR 0·66], wet sponging (OR 0·65), and taking a shower (OR 0·68).[19] Furthermore, whether the intervention improved the participants' ability to recognise other heat-related symptoms such as headache, nausea, vomiting, muscle aches, cramping, and seizures is still unclear.[19] A study[27] from Canada reported no significant difference in awareness of heat-related events between the intervention and control groups, as both groups were highly informed of the heat episode (intervention: 75·6% *vs* control: 68·0%, p<0·08). Only two studies examined heat literacy among vulnerable groups. An Australian study[32] found that individuals on medications were often unaware of the

	Sample size	Age, sex, and ethnicity	Study design	Areas affected by intervention	Heat literacy	Behavioural adaptation	Health-related outcomes	Cost-effectiveness	Confounder assessment	Intervention evaluation	Duration of evaluation	Study quality*
Kuniyoshi et al (2023),[25] Japan	I: 31; C: 28	I: 6·2% men, 93·8% women, mean age 75·6 years (SD 4·9); C: 21·4% men, 78.6% women, mean age 77·9 years (SD 4·6)	Non-randomised trial	Behaviour: time of AC use, fluid intake, checking temperature and humidity, number of people sharing information, recognition of heat disorders, and prevention behaviours	The intervention group showed significant improvement (p<0·05) in T2 and T3 compared with T1 in recognition of heat disorders (medians and ranges are: T1: 42·0 [17–57]; T2: 52·0 [34–60]; and T3: 54·0 [43–60]). There was no difference between T1 and T3 in control groups	The intervention group showed significant improvement (p<0·05) at follow-ups (T2 and T3) compared with baseline (T1) in water intake (mL) with medians and ranges of: T1: 1200 [300–500]); T2: 1800 [800–3500]; and T3: 1800 [800–4000], temperature and humidity checks per day (medians and ranges: T1: 4·0 [2–8]; T2: 6·0 [3–10]; and T3: 5·0 [3–10])	Heat disorders rate in the summer was significantly lower in the intervention group than in the non-intervention group (17·2% *vs* 44·4%, p<0·05)	N/A	N/A	T1: pre-intervention evaluation (July, 2022); T2: mid-intervention evaluation at one and a half months after the intervention began (August, 2022); T3: post-intervention (September, 2022)	1·5 months	3/5
Razzak et al (2022),[19] Pakistan	I: 8668; C: 9877	52·69% men, 47·31% women; 87% of participants were younger than 45 years, and 1·5% older than 65 years	RCT	All-cause mortality, unplanned hospital visits, heat illness, and knowledge and practice related to extreme heat exposure during the summer months of 2017 (pre-intervention) and 2018 (post-intervention)	Households in the intervention group were 2·37 times more likely to recognise high temperature as a symptom of heat illness than the control group; the intervention group showed higher recognition of symptoms, including weakness (OR 1·72) and tachycardia (OR 1·31)	Taking a shower (OR 0·68), avoiding going outside in the afternoon (OR 2·78), and modifying time to cook (OR 1·94) were more acceptable at post-intervention in the intervention group	There was a 38% (aOR 0·62, 95% CI 0·49–0·77) reduction in hospital visits in the intervention group compared with the control group, but no significant difference in all-cause mortality between groups	N/A	Group x time, family size, head of household's education, water source, electricity, television, and house and roof material	Intervention: March to April, 2018. community surveillance (May to July, 2017); post-intervention KAP evaluation (September–October 2018)	5–6 months	3/5
Xu et al (2018),[26] China	I: 1140; C: 1100	1084 men and 1272 women; 1425 urban and 931 rural residents; and 502 participants older than 60 years	Quasi-experimental, non-randomised trial	Knowledge, attitude, and practice scores of the participants	Mean knowledge, attitude, and practice scores in the intervention group were higher in 2015 than in the intervention group in 2014; the intervention was positively associated with increased knowledge (ß=0·387, p<0·001) and attitude (ß=0·166, p<0·01)	No statistical difference in the mean scores of practices of the intervention group compared with those of the control group	N/A	N/A	Time, group, group x time, gender, age, education, Hukou, marital status, occupation, and income	Pre-intervention KAP evaluation (September, 2014) Post-intervention KAP evaluation (September 2015)	1 year	5/5

(Table 1 continues on next page)

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(Continued from previous page)												
Mehiriz et al (2018),[27] Canada	I: 662; C: 666	1328 participants; 75% women, 25% men; 87% of participants older than 65 years, and 69% had chronic illnesses related to heat vulnerability	RCT	Behaviour: drinking water, reducing physical activity, taking cool showers or baths, visiting cool or air-conditioned places, going outside during the heat episode, staying in the shade, and use of fans and AC; health: awareness of heat episodes, had heat-related symptoms and used the health-care system	N/A	The intervention group, compared with controls, was more likely to mention recommended behaviours, citing 2·3 of the 7 measures *vs* 2·1 for the control group (p=0·02). The interventons included increase water consumption (4·19 *vs* 4·04, p=0·02), taking cool showers (81·4% *vs* 73·6%, p=0·04) , spending time in places that are cool or have AC (3·57 *vs* 3·28, p=0·001), and health-care use (among women with chronic illness; 6·2% *vs* 13·5%, p=0·04)	No significant associations observed between frequency of the use of fans, AC, and the risk of having heat-related symptoms	N/A	Differences between estimators of the two groups concerning heat-related illness and frequency of using fans	Pre-intervention evaluation at the beginning of study (June 25 to July 14, 2015); mid-intervention evaluation, after the first heat episode without automated heat warnings (July 27 to 29, 2015); post-intervention evaluation (August 16–19, 2015)	1 month	4/5
Liotta et al (2018),[28] Italy	I: 6483; C: 5724	I: 62·0 % women, 38.0 % men; C: 58.5% women, 41.5% men; mean: 82.3 (SD 0.35)	Quasi-experimental, retrospective cohort study	Mortality rates	N/A	N/A	The Long Live the Elderly (LLE) programme showed a reduction in mortality during the summer of 2015. The mortality rate in urban areas with the LLE programme was 25% (95% CI 23–29), whereas in urban areas without the programme it was 29% (95% CI 17–43); greater increase in deaths observed during the summer of 2015 *vs* 2014, in urban areas without the LLE programme (more 97·3% *vs* more 48·8%); the LLE programme was associated with a decrease in mortality during the summer of 2015 (β=0·217; p<0·001)	N/A	Pre-summer 2015 mortality, proportion of those older than 90 years, intervention (presence *vs* absence)	Pre-summer (October, 2014 to May, 2015) and post-summer evaluations (October to November, 2015)	5–12 months	3/5

(Table 1 continues on next page)

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(Continued from previous page)												
Krackowizer et al (2017),[29] Australia	I: 216; C: 218	Mean age 79.9 years (min 65; max 102); I: 50% women, 50% men; C: 57.8% women, 42.2% men	RCT	Behavioural changes during extreme heat and heat-related health outcomes (anxiety, dizziness, falls, headache, respiratory, heat stress, and heart and renal problems)	More people in the intervention group believed that they had enough information to beat the heat (94% *vs* 88%)	Proportions of participants who used AC during hot weather (74·4% *vs* 63·4%) were concerned about the cost of AC (44% *vs* 39%), and used a wet cloth on their face, neck, or body (16% *vs* 8%) were significantly higher in the intervention group compared with the control group	The intervention group showed a higher prevalence of dizziness (20% *vs* 13%) and headaches (28% *vs* 20%) but reduced heat stress (8% *vs* 19%) compared with the control group; during summer 2014, heat stress was reduced by 63% in the intervention group (aRR 0·37; 95% CI 0·22–0·63)	N/A	Medication for mental health, health status, and use of walking aids	End-of-study survey after summer (2013–14) to assess changes in their behaviours and health experiences related to extreme heat during the intervention period	3 months	4/5
Li et al (2016),[30] China	2240	Aged 4 years or older	Quasi-experimental, non-randomised trial	Prevalence of heat-related illness	NA	NA	Heat-related illness was lower in the intervention group (OR 0·745, p<0·01), but the association was not significant after adjustments. At the township level, the intervention group showed a greater reduction in heat-related illness (0·495, p<0·001). Prevalence in the intervention group decreased by 10·5%, from 30·7% (2014) to 20·2% (2015; p=0·014)	The intervention group has a lower CER than the control group (15·06 *vs* 15·69). The ICER (US $ 7·17–$29·77) was lower than GDP per capita ($12 076), indicating the strategy was cost-effective	Group, time, and group x time interaction term, sex, age, education, Hukou (household registration), marriage, occupation, and income	Pre-intervention evaluation (September to October, 2014); post-intervention (September to October, 2015)	1 year	5/5

(Table 1 continues on next page)

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(Continued from previous page)												
Takahashi et al (2015),[31] Japan	I: 508; C: 508	Aged 65–84 years	RCT	Behaviour: use of AC and electric fans, and actions of the participants to prevent heat-related illness. Heat literacy: awareness or steps to prevent heat-related illness (frequency of alcohol intake, water intake, cooling of the body, taking a rest, reduced activities during daytime, type of clothing, and use of hats or parasols outside)	The control group showed a significant improvement in knowledge (p<0·001), whereas the HHW+W group showed marginal or non-significant improvement (p=0·064)	In the HHW+W group compared with controls, the OR was higher for night-time AC (1·49, 95% CI 1·01–2·19, p=0·047), improvements in water intake (1·77, 95% CI 1·2–2·58, p=0·003), cooling body (1·87, 1·26–2·80, p=0·002), and reduced activities in the heat (1·54, 95% CI 1·01–2·37, p=0·047). In the HHW+W group, compared with controls, improvements in reduced activities in the heat (1·40, 95% CI 0·95–2·07, p=0·093), and hat or parasol use (1·80, 95% CI 1·17–2·77, p=0·008)	N/A	N/A	Sex, age, education, family structure, employment, community involvement, frequency of listening to the radio, and residential type	Evaluations were conducted before (June, 2012) and after (August, 2012) the 9-week intervention period	9 weeks	3/5
Oakman et al (2010),[32] Australia	476	49% men, 51% women; aged 18–65 years or older	Cross-sectional study	Heat literacy: knowledge and behaviours in heat health and heat stress management. Carers of older or disabled people and people with children were asked to describe the heat management strategies they used.	74% of participants heard messages on television, 42% on the radio, and 15% saw messages in newspapers. 78% recognised heat stress symptoms and treatments. The majority of individuals who are on medications had not discussed heat effects with their doctors. Women and carers of older people, disabled people, and children were well informed about heat-related risks	Most participants (54%) stated that they had changed their summer behaviour. Reported water intake increased by 50% during the warmer months	20% of participants had heat-related symptoms during the summer. The majority believed they were coping sensibly with the heat, but some reported heat stress problems	N/A	N/A	The intervention ran mid-December, 2008 to April, 2009. Endline evaluation of the intervention was conducted 2·5 months–3 months after intervention (March 3–19, 2009)	2·5–3 months	4/5

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need to discuss heat-related effects with their doctors. Only 10% of participants enquired about possible adverse effects of their medications during hot weather. This finding contrasts with results showing that women and caregivers were more alert to heat risks, indicating a heightened perceived risk among caregivers for the wellbeing of others. In a US study,[33] a significantly high number of participants remained unconcerned about heat-related illness and often perceived hot weather as a natural occurrence.

Seven studies showed greater improvement in protective behaviours in intervention groups including: adjustments to outdoor behaviours (eg, use of a hat or parasol)[31] and activity timing (eg, avoiding cooking or outdoor exposure during peak heat periods);[19,31] indoor measures (eg, use of air conditioning[27,29] and fans[33] and monitoring indoor temperature and humidity);[25,33] and personal active cooling behaviours such as keeping hydrated,[25,27,31,32] taking a shower,[27] using wet cloths,[29] or using any means of cooling methods.[31] Despite significant associations between the intervention and knowledge and attitude, the interventions introduced in China did not significantly improve the heat adaptation practices.[26] In fact, other studies have indicated no significant difference between the intervention and control groups for some behavioural adaptations including cooling the house (eg, use of blinds), use of fans and air conditioning, showering, wearing lighter clothing, staying indoors, allowing cool breezes in, increasing fluid intake, or avoiding alcohol intake.[27,29,31]

An Australian study[29] reported a 63% lower likelihood of heat stress in the intervention group (incidence rate ratios 0·37) compared with the control group. Other studies reported that most participants did not experience heat-related symptoms post-intervention.[25,29,30,32,33] However, a study[30] in China found no significant reduction in heat-related illness after adjusting for confounders, despite an initial 10·5% decrease in prevalence. Similarly, a study in Canada found no significant difference in self-reported heat-related symptoms between intervention and control groups.[27] Regarding mortality outcomes, findings were mixed. One study[28] reported reduced all-cause mortality during summer (β=0·217, p<0·001), but there was no significant difference in all-cause mortality.[19] Other studies also found an overall reduction in hospital visits (OR 0·62) among intervention groups,[19] and reduction of health services use, but only among women and individuals with chronic illnesses.[27]

Only one study from China did an economic evaluation.[30] The study reported that the intervention group showed a lower cost-effectiveness ratio than the control group, suggesting that implementing the intervention was more cost-effective in reducing heat-related illness. A sensitivity analysis from the same study also confirmed that intervention costs were acceptable relative to economic standards (gross domestic product

(Continued from previous page)

	Sample size	Age, sex, and ethnicity	Study design	Areas affected by intervention	Heat literacy	Behavioural adaptation	Health-related outcomes	Cost-effectiveness	Confounder assessment	Intervention evaluation	Duration of evaluation	Study quality*
Mattern et al (2000),[33] USA	34	82% women, 18% mean; older than 65 years; and African American 97%	Prospective cohort study	Behaviour: identification of contacts for assistance during hot weather (individuals who would contact the City of Philadelphia heat hotline), frequency of thermometer use, and awareness of higher temperatures at homes.	An increased awareness was observed among the participants regarding whom to contact for assistance during hot weather (32 [94%] of 34). Many participants (62% pre-test, 76% post-test) were not concerned about heat-related illness.	Ten (33%) of 30 of the participants who had never become sick from the heat attributed it to fan use; 14 (41%) of 34 reported using a fan, 33 (97%) of 34 reported using the thermometers provided since the intervention, with 25 (76%) of 33 using them daily.	30 (88%) of 34 participants never suffered from heat-related illnesses; a similar percentage were unaware of any family or friends being sick from the heat.	N/A	N/A	Pretest assessment at the start of study and follow-up evaluations 8 weeks after the intervention.	8 weeks	2/5

Age shown to the nearest whole number of years.T1=Test 1. T2=Test 2. T3=Test 3. AC=air conditioner. aRR=adjusted relative risk. aOR=adjusted odds ratio. C=control group. CER=cost-effectiveness ratio. GDP=gross domestic product. HHW+W=heat health warning and water delivery. I=intervention. ICER=incremental cost-effectiveness ratio. N/A=not applicable. OR=odds ratio. RCT=randomised controlled trial. *Study quality based on the MMAT tool score to assess risk of bias (score 4–5: low risk, score 3: fair, and score 1–2: high risk).

Table 1: **Summary of intervention studies**

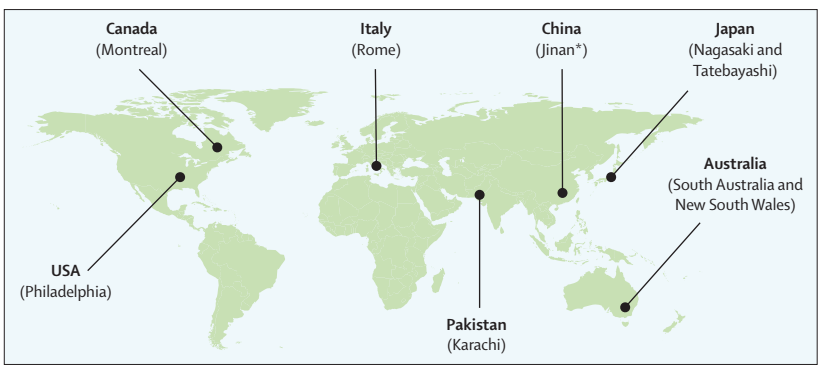

Figure 3: **Location of the included studies**
*Two studies are from the same study population and location.

per capita), suggesting optimal strategies for mitigating heat-related illness.

Discussion

This systematic review identified studies evaluating the effectiveness of CBHA behavioural interventions aimed at improving heat literacy, clinical and health outcomes, and heat adaptation behaviours at household and individual levels. Our review highlights that community-based studies show effectiveness, particularly in heat literacy, behavioural adaptation, and health outcomes, despite most modules primarily focusing on preventive measures during hot weather.

This Review identified a few studies (n=10) assessing CBHA interventions. Most of these studies were done in HICs and were targeted at older populations. The low number of studies from LMICs restricts the generalisability of findings to these regions, where heat-related challenges might be most profound. Although previous reviews focused on population-level heat action plans,[7,15] our review specifically identified studies that were implemented at the community level targeting individuals and households. Additionally, our review identified the issue of heterogeneity of interventions, which makes generalising findings across contexts challenging.

Most studies included in this review might not fully account for the unique characteristics and needs of local communities, which can result in implementation of less effective or less relevant interventions that often do not address specific local challenges.[34] One notable exception is a study by Razzak and colleagues[19] that tried to tailor its intervention to community needs. In this cluster-randomised, community-based trial done in a low-income urban community in Pakistan, the intervention was initially developed by expert panels and key stakeholders. The intervention was then tested in a pilot study to gather participants' feedback. Based on the community response, the usual recommendations for air conditioning and excessive bathing were excluded from the heat adaptation guidelines due to insufficient access to electricity and water in the area.[19,34] The culturally sensitive CBHA educational intervention successfully improved knowledge and practices related to heat-related illness and led to a 38% reduction in hospital visits within a year for the intervention group compared with the control group.[19] In addition, some studies developed and evaluated the effectiveness of age-specific intervention programmes for older adults at risk of heat-related illness. These interventions included providing not only culturally sensitive educational materials but also resources tailored to specific age-related needs of this group.[28,29,33] This approach underscores the importance of understanding local needs and challenges, which facilitates implementation of interventions that address specific community issues instead of applying generic solutions.

Previous heat adaptation research has primarily focused on heat action plans and health educational campaigns.[6,7] Heat action plans usually use broad, systematic strategies that prioritise monitoring systems and educational campaigns aimed at general preventive measures by public health authorities, with evaluations relying on aggregated mortality data. By contrast, community-based educational interventions focus on local engagement, offering culturally tailored resources and information designed to enhance individual knowledge and adaptive behaviours related to heat-related illness prevention.

Within this context, numerous studies have explored community vulnerability and resilience to heat-related health effects, offering key recommendations for heat-health educational behavioural interventions. For example, Lusambili and colleagues[35] conducted a co-design workshop with pregnant and postpartum mothers in Kenya to develop heat mitigation strategies. The researchers identified harmful sociocultural practices, such as expectations for mothers to work immediately after delivery and the excessive layering of clothing on newborns during heatwaves.[35] Other qualitative research from various communities has also provided recommendations for CBHA strategies, which aligned with the intervention recommendations in the studies included in this review, such as cooling strategies for both outdoor and indoor practices.[36–39] Pasquini and colleagues[36] found that residents of informal settlements had little knowledge of heat effects on health and struggled to interpret temperature, which might have constrained their adaptive capacity. Additionally, poverty, inadequate access to clean water, and little of control over living and working conditions further impeded people's ability to adopt effective adaptive behaviours.[36]

Furthermore, the interventions implemented thus far have not been sufficiently informed by behavioural theory and heat literacy frameworks. This absence of integration suggests that these interventions might not have effectively identified possible barriers to adaptation, particularly behavioural factors that influence health outcomes. Integration of theories or frameworks is still low in the context of CBHA intervention research.

	Intervention module	Duration	Frequency	Mode of delivery
Kuniyoshi et al (2023),[25] Japan	Education on heat disorders mechanisms, symptoms, and prevention methods; and daily wet-bulb globe temperature measurements	9 weeks	Once a week	DVD video, face-to-face meeting at salons, telephone call, and leaflet
Razzak et al (2022),[19] Pakistan	Education on prevention of and early recognition of heat-related illnesses; discussion of the risk factors, symptoms, and preventive measures, including dietary modifications; and recognition and early management of possible health-related illnesses	8 weeks	Four visits per participant, 20–25 min per session	Pamphlets in Urdu and Sindhi languages, face-to-face community health worker visits, and neighbourhood meetings
Xu et al (2018),[26] China	Dissemination of knowledge and information about preventive practices during heatwaves	4 months	N/A	Pamphlets, telephone hotline, WeChat application messages, and professional advice about protection during high temperatures and heat waves provided to people who visited a doctor's clinic
Mehiriz et al (2018),[27] Canada	Announcement of forecasted high temperature and provision of tips to help people protect themselves from heat, such as: avoid physical activity; drink plenty of water; use a fan or an air conditioner; take cool showers and baths; spend time in cool or air-conditioned places; stay in the shade when outdoors and wear light clothing; in an emergency, call 911 (emergency services); and for health-related questions call 811 (24/7 health information services)	5 days	66 s telephone call. A reminder call on the second day of heat episode	Automated telephone warning system
Liotta et al (2018),[28] Italy	Sharing tips for hot weather	N/A	Once every 2 weeks, unless needed; one to four calls per participant	An individual care plan is drafted (including the services needed, even if the programme will not provide these services, but will facilitate their provision to the client), periodical telephone calls, electronic staff interventions with a home visit, bringing food and medicines as necessary, or involving the client's network of relationships
Krackowizer et al (2017),[29] Australia	Distribution of Top Tips Heat-Health card and Beat the Heat (fridge magnet); the South Australia Health Department's Extreme Heat Booklet—a guide to coping and staying healthy in the heat; and three South Australia Health advice fact sheets (Advice For An Older Person, Caring For An Older Person, and Safe Food Handling During Extreme Heat)	14 weeks	Once at baseline	Letter, leaflet, laminated card, fridge magnet, booklet, and fact sheets
Li et al (2016), China[30]	Dissemination of knowledge and information about preventive practices during heatwaves	4 months	N/A	Pamphlets, telephone hotline and WeChat service, and workshops or training sessions provided for doctors
Takahashi et al (2015),[31] Japan	Issuing health warnings about heat-related illness prevention or distribution of two 500 mL bottles of water with short messages about heat-related illness prevention behaviours	9 weeks	Once a week for 5 weeks	Audio terminals installed in each household, bottled water with written short messages, and written pamphlets with baseline questionnaires
Oakman et al (2010),[32] Australia	Implementation of Beat the Heat: Don't Forget Your Drink—a public campaign on heat management and heat stress	4·5 months	Once (mid-December, 2008 to April, 2009)	Written materials (posters, brochures, and fact sheets), television, radio, and newspapers and presentations and info sessions at community events
Mattern et al (2000),[33] USA	Encouraging participants to seek appropriate heat-related resources at key temperatures clearly marked on the provided thermometers and culturally sensitive and age-specific heat-related manual	10–15 min	10–15 min once at baseline	Face-to-face meeting, and heat-related manual (written format)

NA=not available.

Table 2: **Types, contents, and delivery strategies for community-based heat interventions**

However, transtheoretical and health belief models are widely used theories that have facilitated the development of effective intervention programmes in community health research.[40] Other previous research studies have successfully implemented frameworks for delivering non-communicable disease prevention programmes.[41] Implementation science theories, models, and frameworks aim to guide the research-to-practice process, identify factors influencing implementation, and evaluate outcomes.[41] These frameworks include process frameworks such as Knowledge to Action and Collective Impact; evaluation frameworks including Reach, Effectiveness, Adoption, Implementation, Maintenance; and determinants frameworks, such as the Strategy Mapping Exercise.[41] Integrating a comprehensive heat adaptation framework into the planning and implementation of research is crucial for researchers and policy makers to gain a thorough understanding of the multifaceted factors affecting human adaptation to heat.[42,43] Such insights can guide targeted interventions and ultimately enhance the effectiveness of CBHA strategies to achieve desired outcomes.[42,43]

This review has identified several issues related to the implementation of CBHA interventions, including the heterogeneity of these interventions, absence of localised context, inadequate consideration of community needs and barriers to intervention, and absence of behavioural frameworks in the planning and evaluation of each study. Future research is needed to address these gaps and develop more effective, context-specific strategies for heat adaptation.

CBHA modules primarily focused on recognising heat-related symptoms and preventive measures and paid little attention to disease mechanisms,[25] risk

factors,[19] and environmental monitoring (eg, checking indoor temperature and local weather).[25,27,33] Most studies addressed heat literacy but were not sufficiently comprehensive to effectively elicit perceived risk susceptibility among community members, as supported by previous reviews.[6,7] Preliminary studies utilising the health belief model have indicated that a basic understanding of how heat can lead to health problems is important for influencing heat adaptation practices. Individuals with a higher perception of heat-related risk are more likely to engage in adaptive behaviours during heatwaves. This finding emphasises the role of understanding the mechanisms of heat-related illnesses in motivating proactive action.[44] However, for individuals with low heat literacy, simple, actionable messages that emphasise recognising symptoms, knowing when to seek help, and taking preventive measures could be more effective than detailed explanations. Tailoring educational materials to align with local literacy levels and cultural contexts further enhances the accessibility and understanding of heat-related illness prevention.

There is currently no consensus on specific definitions of heat literacy. The closest concept, described by Reismann and colleagues,[45] includes understanding the immediate and long-term health effects of climate change and recognising the health co-benefits of adaptation behaviours.[45] However, this definition does not fully cover core health literacy components, such as accessing, understanding, appraising, and applying health information for daily health-care decisions, disease prevention, and health promotion to improve quality of life.[46] Therefore, further investigation into these concepts could lead to more effective interventions, policies, and educational strategies that enhance public understanding and preparedness for heat-related health challenges.

Our analysis showed that heat literacy and awareness messages were commonly disseminated through printed materials (eg, leaflets and brochures) and some studies provided direct support, such as home visits and distributing water bottles and thermometers.[26,30] Digital technology use (ie, mobile applications and internet services) might substantially expand the reach of information dissemination; however, internet access in LMICs is limited, so implementation of digital technologies might be challenging in those areas. Sociocultural factors also influence heat adaptation, highlighting the need to prioritise sustainable measures suitable for low-resource settings, particularly those related to food preparation and clothing.[19] One study[19] provided accessible and tailored preventive measures that do not require excessive water and electricity consumption for communities of low socioeconomic status. Some studies also emphasised the importance of capacity building among local health-care providers.[26,30] Collaborating with local leaders, religious figures, and celebrities can effectively encourage community members in LMICs to adopt safe practices, as culture and religion are pivotal in facilitating behaviour change within these communities.[47,48] Behavioural interventions are often more effective when supplemented with supportive measures such as social support,[49] financial incentives, and structural changes (eg, tree planting, external window shutters, reflective cool roofs, and green architecture) that can mitigate heat build-up and reduce the need for ambient cooling.[50] To our knowledge, no community-based study has yet integrated combined behavioural and structural heat adaptation approaches.

Most CBHA studies have assessed the effectiveness of their interventions through metrics such as heat literacy, and behavioural and clinical outcomes. However, a notable gap remains in the evaluation of cost-effectiveness and other non-clinical outcomes such as quality of life and the mental health effects associated with heat stress. This issue is particularly important given the possible psychological effects of extreme heat, which can greatly affect individuals' wellbeing and coping strategies.[51] By addressing these areas, future research can provide a more comprehensive understanding of the overall effect of heat adaptation interventions on both physical and mental health outcomes. Another limitation is the short post-intervention assessment period, which restricts the evaluation of long-term effects. As a result, clinical outcomes, including reductions in hospital visits and mortality rates, were often not observed[19] and, in some cases, the reduction in mortality could not be directly linked to the intervention, as the specific cause of death was not ascertained.[28]

In our review, most of the included studies reported observable changes in protective behavioural heat adaptation after interventions, covering various strategies for: outdoor (eg, use of a hat or parasol and avoiding outdoor exposure during peak heat periods), indoor (eg, use of air conditioning, a fan, and monitoring indoor temperature and humidity), and personal cooling methods (eg, keeping hydrated, taking a shower, and using a wet cloth to cool down the body). However, there are also studies that reported no significant differences in behavioural adaptation between the intervention and control groups,[27,29,31] suggesting that the interventions might not always be effective at enhancing adaptive behaviours. Some study populations were less concerned about heat-related symptoms and perceived hot weather as a natural occurrence,[32,33] highlighting a possible barrier to adaptation due to absence of self-perceived vulnerability.[7,15]

Direct cooling methods, such as showers and air conditioning units,[25,27,29] were effective but challenging to implement in low-resource settings due to cost constraints.[19] Air conditioners are considered a form of maladaptation due to increased energy use, greenhouse gas emissions, and urban heat island effects.[52] More sustainable options, such as self-dousing with water or use of wet towels,[29] remain underused despite their

effectiveness in reducing heat strain and discomfort.[17] Alternatively, fans can be used as an affordable alternative,[33] but are less effective at ambient temperatures higher than 35°C, particularly for older adults.[53] Evaporative coolers offer a more sustainable alternative with lower energy consumption[19] but require maintenance to prevent mosquito breeding.[17] Passive home measures, such as opening windows and use of awnings, blinds, or curtains, were largely overlooked, despite their effectiveness in maintaining cool indoor environments during hot weather.[54]

The panel summarises recommendations to guide future development and implementation of CBHA behavioural studies, focusing on: methodological considerations, outcome domain measures, content of intervention modules, intervention delivery, and sustainability. Among the key recommendations, methodological considerations should be prioritised in the planning and evaluation of CBHA intervention studies. Further research is essential to understand the needs and challenges of implementing suitable CBHA interventions at the individual and household levels.[55] In this context, a participatory, qualitative approach will be invaluable for exploring community perceptions, experiences, and needs related to heat adaptation, enabling the development of culturally sensitive strategies.[56] Interventions should be tailored to individuals with pre-existing conditions[57] and people with little access to resources.[58] Co-designing interventions[59] with the community can ensure that interventions address specific needs, overcome delivery challenges, and resonate with the target audience, including exploring traditional practices.

Implementation science framework and behavioural theories might also offer valuable approaches for developing culturally sensitive approaches[59] that enhance the effectiveness of interventions by addressing key psychological determinants of health. For example, a study[60] applying the protective action decision model identified key psychological determinants of household-level heat adaptation, including threat and coping appraisal, which predict protection motivation, and general self-efficacy and heat risk perception, which influence heat adaptation behaviours.[60] In a study[61] based on the health belief model, high perceived benefit (OR 2·14), strong cues to action (OR 3·71), higher education levels (OR 2·65), and higher income (OR 2·66) were identified as significant predictors of heat adaptation behaviours. This finding underscores the model's usefulness in understanding cognitive factors that shape individuals' perceptions and behaviours for developing effective heat adaptation interventions.[61] Meanwhile, a study among older adults found that theory of planned behaviour (ie, attitude, perceived social pressure, and perceived behavioural control) markedly affected the intention to adapt, which was linked to heat adaptation behaviours.[62]

***Panel:* Recommendations for future studies**

Methodological considerations
- Understanding needs and challenges through participatory approaches
- Applying relevant theories and frameworks (eg, behavioural theory, heat literacy, and implementation science)
- Co-production of culturally sensitive and tailored interventions with the community; longer follow-up times
- Consideration of seasonal changes

Outcome domain measures
- Heat literacy (eg, perceived susceptibility to heat-related illness and understanding of risk factors, disease mechanisms, and sustainable protective measures)
- Health-related or clinical outcomes (eg, hospital admission, ambulance calls, heat-related symptoms, mortality, mental health, wellbeing, health economic evaluations, and biomarkers)
- Behavioural adaptation

Comprehensive module elements
- Disease mechanisms, risk factors, and symptoms of heat-related illnesses
- Monitoring environmental changes
- Preventive measures and accessible ways of cooling
- Adopting best practices in communicating health messages
- Cultural beliefs, language, social networks, and community participation (contextual factors and historical influences must be considered)

Delivery of intervention
- Collaboration with community and religious leaders, influencers, stakeholders, and other community members throughout the research process
- Use of digital technologies such as mobile phone applications and internet services
- Additional support through financial incentives and structural interventions

Sustainability
- Multisectoral support from academic institutions, local stakeholders, and international organisations
- Leveraging other available resources (eg, Ministry of Health and Global Heat Health Information Network)
- The role of collaboration with funders, particularly in supporting researchers from low-income and middle-income countries

Additional key themes highlight the importance of a well defined study plan with comprehensive intervention modules. Multiple outcome domains for evaluation and longer follow-up periods should be considered at both individual and household levels to better establish causal relationships between

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interventions and their effectiveness across different settings. Although a comprehensive approach to study design is essential for achieving effective CBHA interventions, it is equally important to recognise and address the limitations posed by data and resource constraints in climate and health research, particularly in LMICs. Future research should focus on developing adaptable frameworks that account for these limitations while maximising their effect on health outcomes. Additionally, future research should aim to formulate more detailed research questions that allow for comparisons within specific health outcomes of interest across multiple domains, including heat literacy (eg, knowledge of heat-related risks and preventive measures), clinical effects (eg, incidence of heat-related illnesses and health outcomes), non-clinical effects (eg, psychosocial factors and quality of life), and economic evaluations that assess the cost-effectiveness of interventions. This information will directly affect the decisions about whether to adopt specific interventions in health care or environmental issues. CBHA behavioural interventions must also consider effective communication strategies, cultural beliefs, language, social networks, community participation, contextual factors, and historical influences to ensure they resonate with local values and needs; thereby, the effectiveness and sustainability of these interventions will be enhanced.[63]

In terms of intervention delivery, community-led interventions have been effective in increasing intervention uptake (ie, participation and adherence of community members in CBHA intervention programmes).[19,27,33] Supplementing intervention modules with financial incentives, structural intervention,[64] or digital technologies (eg, videos, apps, and internet services)[33] can further enhance adherence and uptake of the intervention. Measuring individual-level heat exposure with the use of wearable devices offers insights into personal heat risk.[65] These devices can send personalised alerts when temperature thresholds are exceeded, helping users to recognise and respond to potential heat-related health risks. Such devices also have educational benefits by helping users interpret temperature data and make informed decisions about their activities and health during extreme heat.[65] Although direct evidence for the feasibility of wearables in heat adaptation, especially among vulnerable populations, is still poor,[65,66] insights from other areas of digital health research suggest this technology can be successfully used in various health contexts to track physiological metrics and provide real-time feedback.[65,67] With careful design and implementation, wearable technology could help reduce health disparities and improve outcomes for at-risk groups.[67] Although this concept has potential, further research is needed to assess its feasibility and effectiveness in real-world settings, particularly for people most at risk from heat-related health issues.

It is important to leverage available resources and gain support from multisectoral stakeholders (eg, health, education, social services, urban planning, environmental sectors, and research institutes) and international organisations and networks (eg, WHO and the Global Heat Health Information Network) to implement evidence-based heat adaptation interventions aimed at mitigating health effects of extreme heat within the community. In December, 2022, research funding organisations played a crucial role in supporting researchers from LMICs to develop evidence-based interventions, which can help drive policy changes in these countries.[68]

Our review focused on studies that provided measurable outcomes from implemented interventions. Therefore, we might have missed valuable insights from broader programme-based interventions, such as population-level heat action plans, which encompass a range of activities aimed at mitigating heat-related health risks. Our review did not include grey literature, but focused only on peer-reviewed articles, which might have restricted our findings to academically published articles discussing CBHA behavioural interventions. Additionally, the restriction to articles in English in our search might have excluded relevant literature written in other languages, lowering the comprehensiveness of our findings.

Although this review provides insights into the effectiveness of CBHA behavioural intervention studies, several limitations exist. Further research including longer-term assessments, diverse geographical representation, particularly in the LMICs, and broader outcome evaluations to better understand and enhance the effect of such interventions on public health is needed. Future interventions should comprehensively consider multiple aspects of heat literacy, such as perceived susceptibility to heat-related illness, understanding risk factors and disease mechanisms, sustainable and accessible protective measures, awareness of environmental changes, and availability of local resources and multisectoral support regarding heat adaptation. A multidisciplinary approach is necessary to foster the participation and collaboration of various stakeholders in co-designing effective heat adaptation measures to mitigate the health effects of rising temperatures. Co-creating and developing tailored implementation strategies with key stakeholders and communities ensures interventions are both relevant to and effective at addressing barriers identified through theory-informed frameworks within the context of available resources. This approach includes enhancing community involvement in planning and implementation, refining delivery strategies to resonate with the target audience, and promoting engagement with recommended behaviours. Integrating socio-cognitive insights and co-production approaches in heat adaptation intervention programmes can possibly further influence heat adaptation behaviours and attitudes, leading to better adaptation outcomes.

Contributors
HJ curated the data, conducted formal analysis, was involved in investigation, methodology, project administration, handling the software, and data visualisation, and wrote the original draft of the manuscript. FIA was involved in formal analysis, investigation, validation of study, and reviewed and edited the manuscript. YG conceptualised the study, was involved in investigation, methodology, and validation of study, and reviewed and edited the manuscript. TB conceptualised the study, was involved in funding acquisition, and reviewed and edited the manuscript. NKJ, JW, KL, DG, GRLR, KKCL, NM, and TAZ conceptualised the study, and reviewed and edited the manuscript. SB conceptualised the study, was involved in investigation, methodology, validation of study, and reviewed and edited the manuscript. TTS conceptualised the study, was involved in investigation, methodology, funding acquisition, supervision, and validation of the study, and reviewed and edited the manuscript.

Declaration of interests
We declare no competing interests.

Data sharing
This study is based on data extracted from published journal articles. For further inquiries about the study data, please contact the corresponding authors.

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