Public Health 249 (2025) 106046

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

What makes physicians implement climate change and heat adaptation measures in outpatient practices? A mixed-methods study

J. Nieder [a,f], C. Quitmann [a,f], S. Hueber [b], S. Stark [b], M. Klanke [b], D. Shimada [c], J. Lindenthal [c], V. Wambach [c], I. Kaspar-Ott [d], F.J. Alverez [d], E. Hertig [d], A. Herrmann [a,e,*]

[a] Heidelberg Institute of Global Health (HIGH), Faculty of Medicine and University Hospital, Heidelberg University, Heidelberg, Germany
[b] Institute of General Practice, Friedrich-Alexander University Erlangen-Nürnberg (FAU), Erlangen, Germany
[c] Gesundheitsnetz Qualität und Effizienz EG, Nuremberg, Germany
[d] Regional Climate Change and Health, Faculty of Medicine, University of Augsburg, Augsburg, Germany
[e] Institute of General Medicine, Medical Faculty University of Cologne, Cologne University Hospital, Cologne, Germany

ARTICLE INFO

Keywords:
Climate change
Adaptation
Primary care
Mixed methods
Climate resilience
Health system

ABSTRACT

Objectives: Health impacts of climate change are becoming increasingly apparent and require adaptation in the healthcare sector. We aimed to identify behavioural determinants among physicians in outpatient practices for the implementation of climate change adaptation measures with a focus on heat.
Study design: We employed a sequential explanatory mixed-methods design with an online cross-sectional survey and focus group discussions (FGD).
Methods: Data were collected in a physician network in Germany, from April to May 2023. We used Protection Motivation Theory (PMT) as a theoretical model to assess behavioural determinants for the implementation of eight climate change adaptation measures in outpatient practices. Data were analysed using descriptive statistics and logistic regressions and qualitative content analysis for the FGDs.
Results: 67 physicians participated in the survey (62.6 % response rate). On average, physicians reported implementing three out of eight proposed adaptation measures, 91.0 % implemented at least one. In the regression analyses, self-efficacy was a significant predictor for adjusting medication, adjusting schedules, and protecting buildings from heat. Response-efficacy was a significant predictor for educating oneself and the team, informing patients, and advising on active cooling. The FGDs with 18 physicians provided insights into aspects influencing self-efficacy, i.e. lack of time, and response efficacy, i.e. patients' adherence to physicians' recommendations. They also revealed that perceived responsibility for a measure was another determinant outside of PMT.
Conclusion: This study highlights the need to improve physicians' self-efficacy to implement measures, for example by offering clear guidelines. Moreover, it stresses the need to further investigate the effectiveness of single adaptation measures.

1. Introduction

Climate change affects healthcare systems by causing changes in the burden of disease and damage to health system infrastructure, which reduces health system capacity.[1] In Europe and Germany, heat is one major health threat of climate change, especially due to the ageing of societies.[2,3]

Globally and in Germany, health systems are not adequately prepared for climate change impacts such as an increasing burden of adverse health effects of heat.[4] To guide healthcare systems, the World Health Organisation has developed a framework for building climate-resilient and low carbon health systems.[5] One of the frameworks components is a climate-smart health workforce, requiring capacity building among healthcare workers. This includes enabling health professionals to inform patients on climate-adaptive health behaviour.[5] Given that the average German citizen contacts an outpatient physician

This article is part of a special issue entitled: Climate Resilient Health Systems published in Public Health.

* Corresponding author. Im Neuenheimer Feld 324, 69120, Heidelberg, Germany.
E-mail address: alina.herrmann@uni-heidelberg.de (A. Herrmann).

[f] Shared first authorship.

https://doi.org/10.1016/j.puhe.2025.106046
Received 20 February 2025; Received in revised form 22 October 2025; Accepted 6 November 2025
Available online 10 November 2025

at least once a year,[6] outpatient physicians are an important source for climate-related health information[7,8] In a qualitative study with physicians in Germany, four fields of action were identified, in which physicians can change their health care practice to protect the health of elderly from adverse health effects of heat: adjust practice procedures, adapt medication, communicate risks and preventive action and involve the wider social and care network for pro-active contact during heat waves.[9,10] Wider frameworks, such as the WHO guidance for climate resilient and environmentally sustainable health care facilities include a wider focus on building capacity and strengthening preparedness for climate-related health risks.[11]

Awareness for climate change adaptation in outpatient medical practices in Germany seems to be mixed with some practices taking an active role in climate change adaptation and others reacting passively on upcoming hazards.[12] In paediatric outpatient practices in Germany, building-related adaptation measures were commonly implemented whilst providing patient information on the impacts of climate change was less common.[13] Identified barriers for the implementation of climate change adaptation measures include lack knowledge, materials, and clinical guidelines.[12–14] Yet, few studies apply a theoretical model from the behaviour change literature to understand health professionals behaviour with regard to climate change adaptation in outpatient care.

Protection Motivation Theory (PMT)[15] has been suggested as a suitable theoretical model to explain climate change adaptation behaviours.[16] PMT postulates that engagement in protective health behaviours depends on two aspects: (1) an individual's threat appraisal, that is the extent to which they perceive the health problem to be severe ("perceived severity") and the extent to which they perceive themselves to be vulnerable to it ("perceived vulnerability"); (2) an individual's coping appraisal, that is the extent to which they perceive a certain protective behaviour to be effective in protecting their health ("response efficacy") and the extent to which they believe they are able to engage in it ("self-efficacy").[15] This study used PMT to identify behavioural determinants for the implementation of climate change adaptation measures among physicians in outpatient practices. Specific objectives of this study were (1) to determine what kind of adaptation measures physicians are already implementing and (2) to identify behavioural determinants for the implementation of these measures based on PMT.

2. Methods

2.1. Study design and study setting

We applied an explanatory sequential mixed-methods design using a quantitative cross-sectional survey followed by qualitative focus-group discussions (FGD). The qualitative part was designed after preliminary analysis of the quantitative survey to help explain survey results.

The sample consisted of physicians within the practice network "Gesundheitsnetz Qualität und Effizienz eG" (QuE) in Nuremberg, Germany. Physician or practice networks are regional associations of physician, which try to optimize care through fostering local cooperation and quality management. The QuE is organized as a cooperative and runs a joint network office, which coordinates quality assurance measures, information campaigns, and activities relating to the interests of the practices and patients. The QuE had addressed climate change and health issues, especially with regard to heat health and environmental sustainability in educational events (e.g. medical quality circles) and information campaigns before the project.

2.2. Quantitative data collection and sampling

The survey was conducted online between April 17th and May 26th 2023. We aimed for a full population sampling defining the QuE physician network as our target population. We e-mailed the link to all 107 physicians in 63 outpatient practices of the physician network and advertised the survey through newsletters. Physicians who had not responded to the survey received up to five reminders, including individual e-mails or a phone call.

2.3. Quantitative survey

As there was no standardized tool available to assess the research questions, we developed a new survey aimed at assessing the relevant variables. We reviewed published surveys and integrated existing items where appropriate. The survey comprised 53 items (see Appendix 1.) For the present study, we analysed a subset of 39 items: We assessed sociodemographic factors (age, gender), climate change attitude (using Six Americas Super Short Survey, SASSY[17]) and professional factors (specialisation, professional responsibility[18] and experienced climate impact on work). Furthermore, we investigated the implementation status (yes, no, partly) of eight specific adaptation measures depicted in Table 1 (Appendix 1 Items F-M1). Those adaptation measures were derived from a qualitative study with general practitioners (GPs) in Germany, which defined concrete adaptive measures for out-patient practices, focused on protecting elderly patients from heat[9,10] (Table 1). The adaptive measures from this work were reviewed and refined by the research team consisting of health care and global health researchers, medical doctors, a practicing GP, psychologists and a sociologist with regard to their context-specificity and behavioural component for the physician. We preferred those measures over more general measures of climate-resilience in health care facilities, because they related directly to the lived experience of the physicians with regard to their professional behaviour for climate change adaptation in their outpatient practice. For the formulation of the measures, we decided to speak of hot days and heatwaves as both can be a risk to health.

As the investigated adaptation measures primarily respond to extreme heat, we investigated threat appraisal of heat by assessing 'perceived severity' of impacts of hot days and heat waves on health (Appendix 1 Item C2) and 'perceived vulnerability' of patients (Appendix 1 Item E4.1). Coping appraisal (2) was operationalized by assessing 'perceived response efficacy' (Appendix 1 Items F-M2) and 'perceived self-efficacy' (Appendix 1 Items F-M3) for each of the eight

Table 1
Overview of the eight climate adaptation measures investigated in this study.

Adaptation measure	Abbreviation
In my/our practice, building-related heat protection measures are implemented (e.g. shading through shutters on the external facade).	Implement building-related measures
I regularly advise my patients on the specifics of taking and storing medication on hot days and heatwaves and adjust medication plans if necessary (e.g. antihypertensives, diuretics, insulin).	Advise on medication
I advise my older patients to engage in active cooling on hot days and during heatwaves, e.g. by taking cool showers, cold arm and foot baths or cold compresses.	Advise on active cooling
I inform patients and their relatives about the health effects of climate change and appropriate protective measures (e.g. adapting behaviour during heatwaves).	Inform patients
I educate myself and my team about the health effects of climate change and appropriate health protection measures.	Educate myself and my team
My/our practice adapts its schedules to hot days and heatwaves in the summer months, e.g. by having earlier or later consultation times and cancelling stressful procedures for high-risk patients.	Adjust schedules
I sensitize relatives of vulnerable patients to heat risks and encourage them to visit or call patients daily on hot days and during heatwaves to enquire about their well-being and provide assistance if necessary.	Sensitize relatives
My/our practice informs patients via the available channels (e.g. notices, website, newsletter), about official heat warnings from the 'German Weather Service' and appropriate protective measures.	Communicate heat warnings

adaptation measures in Table 1. Fig. 1 depicts how we applied PMT to this research context. For adaptation measures where patients' adherence to the advice (*advise on active cooling*, *sensitize relatives*, and *advise on medication*) is important for their efficacy, we also assessed perceived patient adherence as potential confounding variable.

The research team developing the survey consisted of psychologists, general practitioners, public health researchers, sociologists, and administrative staff of the physician network QuE. A pre-test was conducted with six physicians not related to the study.

2.4. Quantitative analysis

We used descriptive statistics to analyse sociodemographic factors, professional factors, adaptation measures, and PMT variables. To identify participants' climate change attitude, we segmented participants into the six SASSY types with the online tool provided.[17]

We assessed the fit of PMT for predicting adaptive behaviour by physicians in outpatient care using logistic regression analyses, one for each adaptation measure. The outcome variable was implementation of the respective adaptation measure, re-coded into dichotomous variables combining the responses "no" and "partially" to "no". The predictor variables were 'perceived severity', 'perceived vulnerability', 'perceived self-efficacy', and 'perceived response efficacy' according to PMT (see Fig. 1, Appendix 1). In the regression models for *advising on active cooling*, *sensitizing relatives* and *advising on medication,* patient adherence was identified as a potential confounder in advance and added to the model. We conducted bi-variate analysis between other co-variates (age, gender, SASSY, speciality, professional responsibility, perceived impact on work) and the PMT variables. However, due to low sample size and unclear patterns of association, we refrained from adding other variables to the model. Data were analysed using IBM SPSS statistics V.27 and statistical significance was assumed at a level of significance of $p = 0.05$.

2.5. Qualitative data collection and analysis

FGD were conducted in person in September 2023. Asthe surveys had been anonymous, we were not able to contact physicians based on their answers in the survey. Therefore, we conducted the FGD with a convenience sample of physicians, who voluntarily agreed to participate in a series of meetings within a wider research project, called AdaptNet (Adaptation and networking of general and specialist care with regard to the health effects of climate change). We developed the semi-structured interview guide based on preliminary quantitative results, therefore the guide is presented in the results section. We transcribed the FGD verbatim and analysed the transcripts using content analysis with both a deductive and inductive approach,[19] supported by NVivo 14 (Lumivero). We developed categories deductively based on the quantitative results and the interview guide, while the codes were developed inductively.

3. Results

3.1. Quantitative results

3.1.1. Descriptive results

3.1.1.1. Socioeconomic characteristics, climate change attitude and professional characteristics. A total of 67 physicians (62.6 % response rate) responded to the survey. All responses were included in the analysis. Most (71.6 %) physicians were older than 50 years and the sample was slightly male-dominated (58.2 %). 44.8 % were specialist physicians, and 55.2 % were general practitioners. According to the SASSY, 61.2 % had an alarmed and 29.9 % had a concerned attitude towards climate change. 6 % were cautious and 3 % were doubtful about climate change (Table 2). Most physicians (somewhat) agreed that they have the responsibility to protect their patients from the health effects of climate change (73.1 %). More than half reported experiencing the impacts of climate change in their daily practice (53.8 %).

3.1.1.2. Implementation of adaptation measures. On average, physicians reported implementing three of the eight proposed adaptation measures. 91.0 % implemented at least one, and 4.5 % implemented all measures. The most frequently implemented measure was *implementing building-related measures* (77.6 %), whilst the least frequently implemented measure was *communicating heat warnings* (10.5 %) (Fig. 2). Of note is the frequent response of "partially". Particularly for *sensitizing relatives, informing patients,* and *educating myself and my team* more than 40 % indicated this response.

3.1.1.3. Protection Motivation Theory variables. 'Perceived severity' was high, with 95.5 % agreeing or somewhat agreeing that hot days and heat waves negatively affect people's health. For 'perceived vulnerability', 91.4 % of physicians indicated that they perceive heat-related health threats to be significant or somewhat significant for their patients' health today.

Regarding response efficacy, 32.8 % of physicians (somewhat)

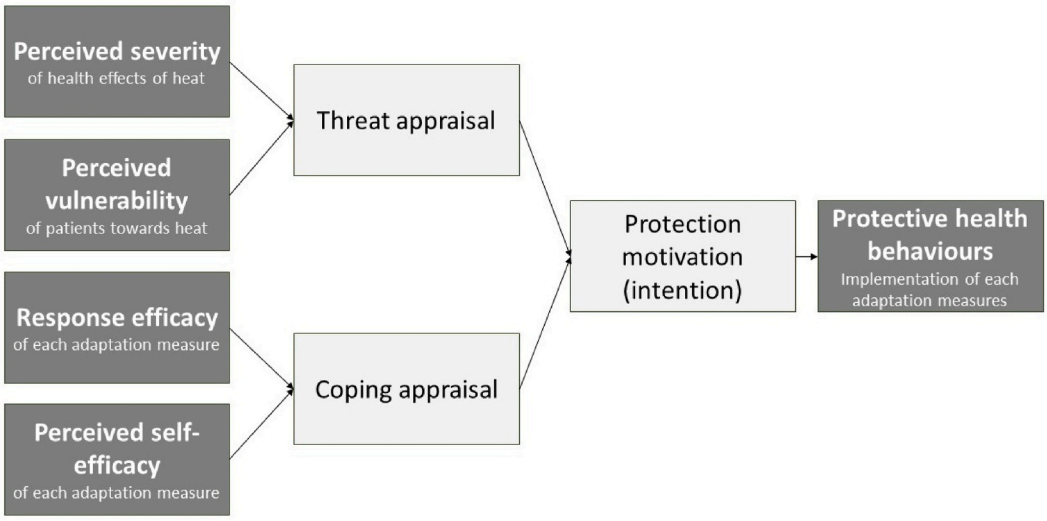

Fig. 1. Protection Motivation Theory by Rogers, 1963, applied to the research context of this study.

Table 2
Sociodemographic characteristics and climate change attitude (SASSY) of survey (n = 67) and FDG sample (n = 18).

	Survey N (%)	FGDs N (%)
Gender	65 (97.0 %)	18 (100 %)
Female	26 (38.8 %)	7 (38.9 %)
Male	39 (58.2 %)	11 (61.1 %)
Other	0	0 (0 %)
Missing	2 (3.0 %)	0 (0 %)
Medical specialisation	67 (100 %)	18 (100 %)
General Practitioner	37 (55.2 %)	13 (72.2 %)
Other Speciality	30 (44.8 %)	5 (27.8 %)
Missing	0 (0.0 %)	0 (0.0 %)
Age	65 (97.0 %)	18 (100 %)
<30	0	0 (0 %)
30–39	3 (4.5 %)	0 (0 %)
40–49	14 (20.9 %)	2 (11.1 %)
50–59	24 (35.8 %)	7 (38.9 %)
>60	24 (35.8 %)	8 (44.4 %)
Missing	2 (3.0 %)	1 (5.6 %)
SASSY	67 (100 %)	Not assessed
Alarmed	41 (61 %)	–
Concerned	20 (29.9 %)	–
Cautious	4 (6.0 %)	–
Doubtful	2 (3.0 %)	–
Dismissive	0	–
Disengaged	0	–
Missing	0	–

agreed that the measures are suitable for protecting their patient's health for all suggested adaptation measures. Agreement to response efficacy was highest for *implementing building-related measures* (88.1 %) and lowest for *adjusting schedules* (56.7 %). Self-efficacy for engaging in suggested adaptation measures was high, with 94 % (strongly) agreeing that they and their practice team are able to implement at least one of the measures and 71.6 % indicating the same for five or more measures. Agreement to self-efficacy was highest for *implementing building-related measures* (86.5 %) and lowest for *adjusting schedules* and *communicating heat warnings* (55.2 % and 55.3 %, respectively).

3.1.1.4. Perceived patient adherence. We found that 53.7 % (somewhat) agreed that patients adhered to their advice regarding *advice on medication*, 43.3 % (somewhat) agreed that patients adhered to *advice on active cooling* and 38.8 % (somewhat) agreed that someone would regularly contact the patient in question when physicians *sensitized relatives*. Table 3 summarizes the mean agreement to perceived response efficacy, self-efficacy, and patient adherence for the eight adaptation measures under study.

3.1.2. Regression model

In order to analyse if and how variables derived from PMT are associated with the implementation of the eight adaptation measures, we conducted eight logistic regression models. All assumptions for a logistic regression were met (see Appendix 3).

For all adaptation measures except *communicating heat warnings*, the models show good fit to the data, indicating that, taken together, the independent variables (severity, vulnerability, response efficacy, self-efficacy) have an effect on the dependent variable (self-reported implementation of adaptation measure). Nagelkerk's R^2 shows that most variance can be explained for *adjusting schedules* ($R^2 = 0.684$), whilst least variance is explained for *implementing building-related measures* ($R^2 = 0.323$). The implementation of *communicating heat warnings* was a rare event with near perfect correlation to predictors, therefore a regression

Table 3
Average agreement to coping appraisal variables (response efficacy, self-efficacy) and patient adherence for eight adaptation measures.

Adaptation measure	Perceived self-efficacy (mean; standard deviation)	Perceived response efficacy (mean, standard deviation)	Perceived patient adherence (mean; standard deviation)
Educate myself and my team	3.9 (1.00)	3.87 (0.97)	
Inform patients	4.22 (0.97)	4.24 (1.00)	
Sensitize relatives	3.51 (1.30)	4.19 (0.94)	3.18 (1.09)
Advise on active cooling	4.16 (1.07)	4.18 (0.92)	3.43 (0.97)
Advise on medication	4.03 (1.33)	3.43 (0.97)	3.61 (0.97)
Adjust schedules	3.57 (1.33)	3.72 (1.19)	
Implement building-related measures	4.42 (1.12)	4.49 (0.88)	
Communicate heat warnings	3.45 (1.31)	3.67 (1.26)	

*All items are responded to a five-point Likert-scale ranging from 1 "disagree" to 5 "agree".

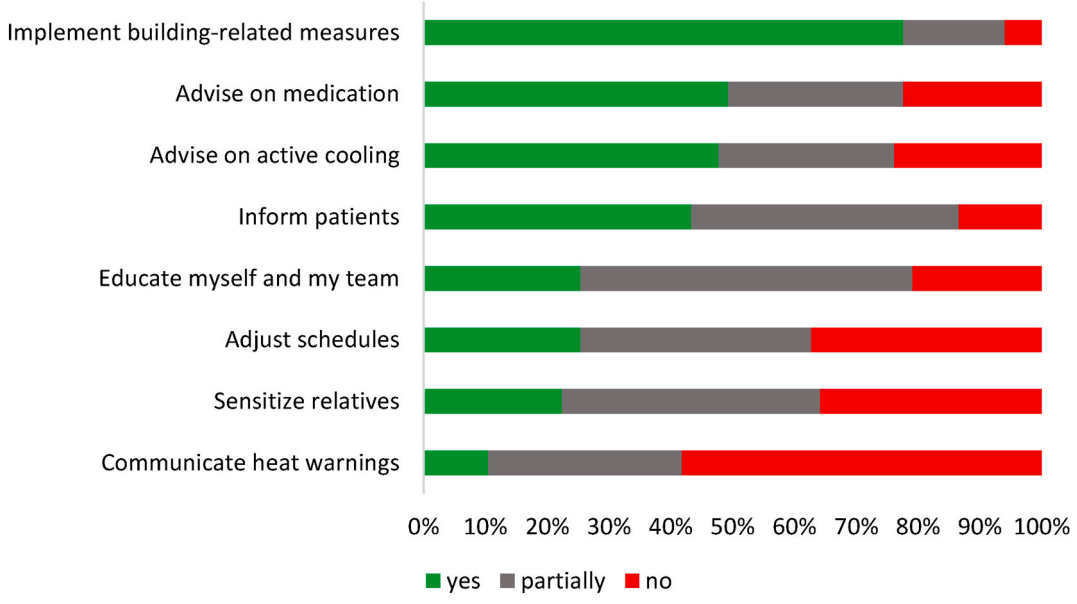

Fig. 2. Stacked bar chart showing the percent of physicians who have, have partially, and have not engaged in the adaptive measures.

model could not plausibly be fit. Where predictors were significant, they were positively associated with the outcome. Perceived response efficacy was a statistically significant predictor for *educating myself and my team* (β = 9.452, p = 0.002), *informing patients* (β = 4.178, p = 0.020), *sensitizing relatives* (β = 3.054, p = 0.021), *advising on active cooling* (β = 6.797, p = 0.001), and *adjusting schedules* (β = 7.461, p = 0.032). Perceived self-efficacy was a significant predictor for *sensitizing relatives* (β = 2.060, p = 0.034), *advising on medication* (β = 4.991, p = 0.005), *adjusting schedules* (β = 6.057, p = 0.037), and *building-related measures* (β = 2.911, p = 0.011). Neither perceived severity nor perceived vulnerability added significantly to the prediction of adaptation measures, with the exception of *advising on medication* (perceived severity: β = 4.295, p = 0.022). The results of the logistic regression analyses are presented in Table 4.

Stepwise regression showed that for *sensitizing relatives,* patient adherence (β = 3.11, p = 0.021) was a significant predictor, causing response efficacy (β = 2.044, p = 0.274) and self-efficacy (β = 1.351, p = 0.485) to no longer be significant. For *advising on active cooling* the addition of patient adherence was significant (β = 2.830, p = 0.032) but did not significantly change other predictors. For *advising on medication* the addition of patient adherence was insignificant.

3.2. Quantitative results as a starting point for deeper qualitative insights

A main finding of the quantitative results was that whilst response and self-efficacy were significant predictors of implementation of adaptive adaptation measures, measures with similar response or self-efficacy differed in their implementation frequency. Therefore, we aimed to deepen our understanding of coping appraisals for different adaptation measures and identify potential other factors beyond PMT that influence implementation. Descriptive results of three adaptation measures (*informing patients*, *sensitizing relatives, communicating heat warnings*) were selected that differed in levels of coping appraisal and implementation, and we confronted physicians with these contrasting results. As many physicians had indicated a partial implementation of certain adaptation measures, we also asked about the meaning of "partially" (see Fig. 2).

3.3. Qualitative results

The two FGD lasted 40 min each and were conducted with a sample of 18 physicians, which was male-dominated (60 %) with an average age of 60 years. Most participants (72 %) were general practitioners and/or internal specialists, while other specializations included surgeons, neurologist or psychiatrists (Table 2).

3.3.1. Coping appraisal and other factors influencing implementation

A commonly mentioned reason for low self-efficacy in *informing patients* was lack of time. It was emphasized that it was more feasible to inform patients during scheduled appointments than during emergency consultations. Patient information materials were perceived as enabling, however, some physicians noted that they did not have such materials. Another reason for lower self-efficacy was perceived lack of guidelines on whom to advise. Similarly, self-efficacy regarding *sensitizing relatives* was impaired by a lack of time and uncertainties about how to contact relatives. Being in direct contact with relatives, for example, during home visits or because the relatives themselves were patients in the same practice was mentioned as helpful. Confidentiality was also cited as a barrier to *sensitizing relatives*.

Perceived response efficacy for *informing patients* was decreased by doubts about the impact on patient behaviour. Similarly, trusting that a patient understands the given information was mentioned as a facilitator. For *sensitizing relatives*, it was added that not all patients had relatives who were able to implement this measure, which was seen as a factor reducing response efficacy. Physicians explained that low response efficacy for *communicating heat* warnings was due to their

Table 4
Logistic stepwise regression analysis table showing the exponentiated coefficient Exp(b), 95 % confidence intervals and significance value p for each coefficient for Steps 1 and 2.

	Variable	**Educate myself and my team**		**Inform patients**		**Sensitize relatives**		**Advise on active cooling**	
		Exp(b) (95 % CI)	**p**	**Exp(b) (95 % CI)**	**p**	**Exp(b) (95 % CI)**	**p**	**Exp(b) (95 % CI)**	**p**
1	Perceived severity	1.024 (0.136; 7.703)	0.981	0.334 (0.072; 1.546)	0.161	0.494 (0.099; 2.459)	0.274	0.607 (0.116; 3.193)	0.556
	Perceived vulnerability	1.084 (0.295; 3.985)	0.904	1.089 (0.367; 3.23)	0.878	1.297 (0.456; 3.69)	0.485	1.082 (0.353; 3.319)	0.890
	Response efficacy	9.452 (2.321; 38.487)	0.002	4.178 (1.251; 13.957)	0.020	3.054 (0.854; 10.925)	0.021	6.797 (2.179; 21.2)	0.001
	Self-efficacy	3.368 (0.954; 11.89)	0.059	2.466 (0.863; 7.046)	0.092	2.06 (1.002; 4.236)	0.034	1.619 (0.757; 3.463)	0.214
2	Perceived severity					0.749 (0.132; 4.244)	0.744	0.626 (0.114; 3.444)	0.590
	Perceived vulnerability					1.16 (0.36; 3.739)	0.804	1.609 (0.435; 5.954)	0.476
	Response efficacy					2.044 (0.568; 7.362)	0.274	4.319 (1.366; 13.654)	0.013
	Self-efficacy					1.351 (0.581; 3.146)	0.485	1.519 (0.654; 3.532)	0.331
	Patient adherence					3.011 (1.185; 7.65)	0.021	2.83 (1.092; 7.335)	0.032
	Constant	0.000	0.005	0.003	0.106	0.000	0.034	0.000	0.007
Hosmer-Lemeshow-Test		X^2 (8) = 6.784, p = 0.560		X^2 (6) = 3.131, p 0.792		X^2 (7) = 2.051, p = 0.957		X^2 (7) = 12.480. P = 0.086	
Model summary		R^2 (Nagelkerk) = 0.600; X^2 (4) = 34.943, p < 0.001		R^2 (Nagelkerk) = 0.411; X^2 (4) = 24.491, p < 0.001		R^2 (Nagelkerk) = 0.395; X^2 (5) = 20.045, p = 0.001		R^2 (Nagelkerk) = 0.523; X^2 (5) = 33.306, p < 0.001	

	Variable	Advise on medication		Communicate heat warnings[a]		Adjust schedules		Protect building from heat	
		Exp(b) (95 % CI)	p	Exp(b) (95 % CI)	p	Exp(b) (95 % CI)	p	Exp(b) (95 % CI)	p
1	Perceived severity	0.137 (0.137; 0.021)	0.038	4.541 (0; 0)	1.000	0.195 (0.023; 1.62)	0.130	0.205 (0.031; 1.365)	0.102
	Perceived vulnerability	1.408 (1.408; 0.454)	0.554	0.889 (0.125; 6.31)	0.906	0.641 (0.122; 3.382)	0.600	2.282 (0.651; 7.996)	0.197
	Response efficacy	1.471 (1.471; 0.391)	0.568	7254888.056 (0; 0)	0.996	7.461 (1.184; 47.018)	0.032	1.002 (0.407; 2.47)	0.996
	Self-efficacy	4.991 (4.991; 1.626)	0.005	9634082.906 (0; 0)	0.995	5.882 (1.208; 28.642)	0.028	2.911 (1.282; 6.61)	0.011
2	Perceived severity	0.103 (0.015; 0.726)	0.023						
	Perceived vulnerability	1.998 (0.563; 7.092)	0.284						
	Response efficacy	1.252 (0.292; 5.373)	0.763						
	Self-efficacy	4.295 (1.371; 13.455)	0.012						
	Patient adherence	2.293 (0.912; 5.765)	0.078						
	Constant	0.081	0.565	0.000	0.996	0.000	0.206	2.168	0.834
Hosmer-Lemeshow-Test		X^2 (7) = 3.264, p = 0.860		X^2 (7) = 0.000, p = 1		X^2 (7) = 1.195, p = 0.991		X^2 (5) = 6.611, p = 0.251	
Model summary		R^2 (Nagelkerk) = 0.541; X^2 (5) = 34.878, p < 0.001		R^2 (Nagelkerk) = 0.570; X^2 (4) = 21.844, p < 0.001		R^2 (Nagelkerk) = 0.684; X^2 (4) = 41.753, p < 0.001		R^2 (Nagelkerk) = 0.323; X^2 (4) = 15.931, p = 0.003	

[a] Rare event and near perfect correlation with predictors, therefore a regression is not suitable.

perception that practices had a lower reach compared to other entities such as mass media. Moreover, one physician thought response-efficacy to be low, because he doubted the accuracy of official heat warnings, as the local weather station was located in a cooler rural area.

Regarding other factors outside of PMT, physicians' professional responsibility for adaptation measures was discussed. Some physicians mentioned that they do not perceive *communicating heat warnings, sensitizing relatives, informing patients,* and other measures addressed in the survey to be their primary responsibility. It was stressed that when time was limited, immediate health concerns of patients had to be prioritized over, for instance, *sensitizing relatives*. Another issue that received attention in the FGDs was patient autonomy. For instance, *sensitizing relatives* was perceived as paternalizing patients and their relatives. The absence of reimbursement was also identified as an obstacle to *sensitizing relatives*.

Table 5 shows quotes from exemplary subcategories. All subcategories including illustrative codes are collated in Appendix 5.

3.3.2. *"Partially" implementing measures*

The item "*are you implementing this measure*" was often responded to with "partially". Physicians explained that this meant that measures were not always or not sufficiently implemented. Reasons for this were related to the patients (e.g., only implemented for patients with risk profiles), the outpatient facility (e.g., implemented depending on the time capacity on different days), or the measure itself (e.g., only parts of the measure were implemented). Fewer physicians said that "partially" could also mean that the measure was not implemented because they *"maybe did not want to say 'no'"* (FGD 2) or would like to implement the measure but are currently unable to do so.

4. Discussion

4.1. Summary

Physicians in this study implemented an average of three out of the eight suggested adaptation measures, most frequently *building-related measures*, *advising on medication* and *advising on active cooling*. PMT could explain some variation in the implementation of adaptation measures, and perceived response- and self-efficacy were identified as important determinants. The qualitative results indicated that for self-efficacy lack of time and clear guidelines hindered implementation. For response efficacy, physicians mentioned low perceived patient adherence as a reason against implementation. Unclear professional responsibilities and issues of patient autonomy were additional barriers.

Table 5
Quotes illustrating the aspects mentioned.

Main category	Exemplary subcategory	Illustrative quote
Self-efficacy	Lack of guidelines	*"There is no guideline, it is very individual who we, for whom we take the time." (FGD 2)*
Response efficacy	Patient adherence to physicians' recommendations	*"There are so many old people, and most of them have dementia, which means that even measures don't work. You call them, they turn round and still don't drink." (FGD 2)*
Other factors	Missing sense of responsibility	*"[…] but we haven't done that [?] with the heat warnings or anything like that, but I think that the patient himself will ultimately receive the information* via *the press and other sources when the time comes for it [heat wave] to happen." (FGD 1)*
	Violation of patients' autonomy	*„I also believe that this would meet with at least some rejection. In the sense of 'what do they want to tell me to do with my grandma? Understanding it as a kind of paternalism. Nobody would want that." (FGD 1)*

4.2. Interpretation of mixed-methods results within existing literature

Higher perceived self-efficacy significantly increased the likelihood of *advising on medication, adjusting schedules,* and *implementing building-related measures*. For *informing patients* and *advising on medication,* qualitative results identified lack of time and guidelines as factors reducing self-efficacy. This is in line with previous studies.[12–14] Self-efficacy can be increased by providing best practice examples and step-by-step guidelines.[20] Therefore, heat health adaptation measures should be integrated into medical curricula and trainings of physicians including concrete guidance material.

Higher perceived response efficacy increased the likelihood of *informing patients* and *advising on active cooling*. Indeed, the available evidence on the effectiveness of individual heat adaptation measures is limited and methodologically challenging.[21,22] Nonetheless, heat health action plans that include concrete adaptation measures in healthcare have proven to be effective.21 In our sample, perceived response efficacy for *informing patients* and *advising on active cooling* was already relatively high. Yet, as our sample had been sensitized for heat health, this is unlikely to be generalizable to all outpatient physicians in Germany. Therefore, heat training for physicians should include evidence of the effectiveness of implementing adaptation measures to increase perceived response efficacy and, subsequently, implementation.

Perceived patient adherence was found to increase the likelihood of *advising on active cooling* and *sensitizing relatives*, and was mentioned as important for *informing patients* in the FGDs. So, whether physicians believed that their patients or patients' relatives would follow advice about active cooling or contacting relatives regularly during heat waves made a difference to physicians' implementation. In contrast Kemen et al. found no difference in heat adaptation behaviour during extreme heat between seniors in Cologne, Germany who had and those who had not consulted their GP about heat adaptation.[23] Yet, well-designed implementation studies are needed, which test the effects of different methods and contents of heat health communication by physicians on patients' behaviours.

Although most physicians agreed that they were responsible for protecting patients from the health effects of climate change, the FGD revealed that they did not feel responsible for all suggested measures. Specifically, physicians thought that other stakeholders are better positioned for *communicating heat warnings*. It seems sensible that physicians' limited time resources should be used for specific behavioural and medical advice during heat waves. Other stakeholders, such as news and weather services, have been identified as suitable for communicating short-term heat warnings.[24] Heat health action plans should indicate clear responsibilities and limit those of health professionals to activities that are clearly within their professional field.

As another factor outside of PMT, violating patient autonomy was mentioned as a reason for not engaging in *sensitizing relatives*. While a study on perception of heat health plans by elderly people in the did not explicitly report on patients' views on "heat buddies", some respondents said that heat health action plans are intrusive UK or patronising.[25] On the other hand, voluntary "buddy-systems" (measures that support personal contact for vulnerable populations during heat waves) are recommended[26] in heat health action plans[27] and have been found to be effective.[21] Therefore, communication with patients and their relatives should emphasise the measures' health benefits while allowing autonomy in the specifics of personalization and implementation.

4.3. Strengths and limitations

It is a strength of this study, that it was able to attain a relatively high response rate in a sample of practicing physicians (62,6 %) where response rates are often low, minimising selection bias within the study

population. The mixed-methods design helped to create a more in-depth understanding of how PMT factors influence implementation of adaptation measures and increases internal validity of the results. Triangulation of the quantitative and qualitative seems to support that PMT is a suitable theory to support climate change adaptation research in health care. However, in the survey, PMT factors were assessed using only one variable in order to maximize participation rate. This may have led to less reliable results compared to using multiple items and latent factors.[28]

Another limitation of the study is the specificity of the study population. The collaborating physician network had previously been educated about climate change and health through information events and information materials. Results are therefore not generalizable to outpatient physicians in Germany. Notably, threat appraisal was high with little variation in 'perceived severity' and 'perceived vulnerability'. This might have biased regression results, which only found coping appraisal ('self-efficacy' and 'response efficacy') to be a significant predictor of implementing adaptation measures. Samples of physicians with more variance in threat appraisal may lead to different results. Another limitation is the small sample size, which may have inflated the odds ratios.

It is of note that the study sample is heavily skewed towards an older generation so that results may not be predictive of future opinions regarding adaptive measures. However, the average age of physicans in Germany was 54 in 2024 and 62.2 % of GPs in Germany were at least 50 years old (Statistische Informationen aus dem Bundesarztregister, KB),[29] suggesting that our sample is reflecting the average age of currently practicing physicians. This is important, as increasing hot days and heat waves are already a threat to human health and therefore, action is needed now.[1]

4.4. Conclusions for research and practice

To our knowledge, this is the first study to comprehensively assess behavioural determinants for the implementation of heat adaptation measures by physicians in German outpatient care. While the sample had been pre-sensitized for climate change and health and threat appraisal was generally high, implementation of adaptation measures was still limited. This is partly due to limited coping appraisal, which means that physicians do not feel able to implement the measure ('self-efficacy') or do not consider the proposed measures to be effective ('response efficacy'). Future research should be directed at evaluating the effectiveness of single adaptation measures more stringently, as physicians (and possibly other stakeholders) seem to be more likely to implement adaptation measures, if they are convinced of their effectiveness. Simultaneously, adaptation measures should be time-efficient and billable and come along with clear and easily understandable guidelines and materials supporting their implementation.

Author statements

Ethical approval

The study protocol was approved by the Ethics Committee of the Medical Faculty at Heidelberg University (S-163/2023). All participants gave written informed consent.

Funding

The project was funded by the Innovationfund of the German Joint Federal Committee (Gemeinsamer Bundesausschuss, 01VSF22044).

Competing interests

EH: none. IK: none. StSt: none. VW none. SU none. MK none. JN none. FA none. AH and CQ received honoraria for educational formats on heat health adaptations for physicians by the Institut für hausärztliche Fortbildung (IHF). AH: non-financial conflicts of interest are being a member at the German Climate Change and Health Alliance (KLUG e. V.) and being a spokesperson of the section climate change and health of the German College of General Practitioners and Family physicians. CQ: non-financial conflict of interest is being a member at the German Climate Change and Health Alliance (KLUG e.V.).

Author contributions

EH, SH, VW and AH conceived the wider study idea of the Adaptnet project and were responsible for funding acquisition. JN, CQ and AH designed the study presented in this paper and drafted the methodology. CQ, JN, SH, SS, MK, DS and JL performed the recruitment and data collection process. CQ conducted the qualitative and JN conducted the quantitative analysis. AH supervised and validated the analysis. CQ, JN and AH wrote the original draft. All authors reviewed and edited the manuscript.

Acknowledgements

We thank Emma Reynolds for translating the quotes of the qualitative focus group discussions.

This research is funded by the Innovationsfond of the Gemeinsamer Bundesausschuss (01VSF22044).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2025.106046.

References

1. Romanello M, di Napoli C, Green C, et al. The 2023 report of the lancet countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *Lancet*. 2023;402(10419):2346–2394. https://doi.org/10.1016/S0140-6736(23)01859-7.
2. Augustin J, Burkart K, Endlicher W, et al. Klimawandel und Gesundheit. In: *Klimawandel in Deutschland: Entwicklung, Folgen, Risiken Und Perspektiven*. second ed. Springer; 2023.
3. Winklmayr C, Matthies-Wiesler F, Muthers S, et al. Hitze in Deutschland: Gesundheitliche Risiken und Maßnahmen zur Prävention. Published online September 6, 2023 https://edoc.rki.de/handle/176904/11262. Accessed August 2, 2024.
4. Sachverständigenrat zur Begutachtung der Entwicklung im Gesundheitswesen. Resilienz im Gesundheitswesen - wege zur Bewältigung künftiger Krisen: Gutachten 2023. Published online 2023 https://www.svr-gesundheit.de/publikationen/gutachten-2023/. Accessed February 21, 2024.
5. World Health Organization. Operational Framework for Building Climate Resilient and Low Carbon Health Systems. 2023. p.24-26. https://www.who.int/publications-detail-redirect/9789240081888. [Accessed 2 February 2024].
6. Statista. *Ambulante Ärztlich Behandelte Personen Und Behandlungsfälle*. Statista; 2024. https://de.statista.com/statistik/daten/studie/75608/umfrage/von-aerzten-behandelte-personen-und-aerztliche-behandlungsfaelle/. Accessed March 15, 2024.
7. Boland TM, Temte JL. Family medicine patient and physician attitudes toward climate change and health in Wisconsin. *Wilderness Environ Med*. 2019;30(4):386–393. https://doi.org/10.1016/j.wem.2019.08.005.
8. Maibach EW, Kreslake JM, Roser-Renouf C, Rosenthal S, Feinberg G, Leiserowitz AA. Do Americans understand that global warming is harmful to human health? Evidence from a national survey. *Ann Glob Health*. 2015;81(3):396–409. https://doi.org/10.1016/j.aogh.2015.08.010.
9. Herrmann A. *Heat Health Impacts and Their Prevention for Elderly in Baden-Württemberg, Germany: A Qualitative Study on General Practitioners' Perceptions and Practices in the Face of Climate Change Inagural Disseration for the Medical Doctorate*. University of Heidelberg; 2018.
10. Herrmann A, Haefeli WE, Lindemann U, Rapp K, Roigk P, Becker C. [Epidemiology and prevention of heat-related adverse health effects on elderly people]. *Z Gerontol Geriatr*. 2019;52(5):487–502. https://doi.org/10.1007/s00391-019-01594-4.
11. *WHO Guidance for climate-resilient and Environmentally Sustainable Health Care Facilities*. Geneva: World Health Organization; 2020. Licence: CC BY-NC-SA 3.0 IGO.
12. Litke NA, Poß-Doering R, Fehrer V, et al. Building climate resilience: awareness of climate change adaptation in German outpatient medical practices. *BMC Health Serv Res*. 2024;24(1):184. https://doi.org/10.1186/s12913-024-10664-2.
13. Edlinger M, Schneider M, Lagally L, et al. [Climate change and child health: A nationwide survey among paediatricians in Germany]. *Z Evidenz Fortbild Qual Im Gesundheitswesen*. 2022;172:102–111. https://doi.org/10.1016/j.zefq.2022.03.007.

14. Mezger NCS, Thöne M, Wellstein I, et al. [Climate protection in practices - current status, motivation and challenges in outpatient care]. *Z Evidenz Fortbild Qual Im Gesundheitswesen*. 2021;166:44–54. https://doi.org/10.1016/j.zefq.2021.08.009.
15. Rogers RW. *Cognitive and physiological processes in fear appeals and attitude change : a revised theory of protection motivation. Soc Psychol Source Book*. 1983:153–176. Published online.
16. van Valkengoed A, Steg L. *The Psychology of Climate Change Adaptation*. Cambridge University Press; 2019. https://www.cambridge.org/core/elements/abs/psychology-of-climate-change-adaptation/F754A13BC739278F87346912664E552E. Accessed February 2, 2024.
17. Chryst B, Marlon J, van der Linden S, Leiserowitz A, Maibach E, Roser-Renouf C. Global warming's "six americas short survey": audience segmentation of climate change views using a four question instrument. *Environ Commun*. 2018;12(8):1109–1122. https://doi.org/10.1080/17524032.2018.1508047.
18. Sarfaty M, Kreslake J, Ewart G, et al. Survey of international members of the American thoracic Society on climate change and health. *Ann Am Thorac Soc*. 2016;13(10):1808–1813. https://doi.org/10.1513/AnnalsATS.201604-229BC.
19. Kuckartz U. *Qualitative Inhaltsanalyse: Methoden, Praxis, Computerunterstützung*. Beltz Juventa; 2012.
20. Picha KJ, Howell DM. A model to increase rehabilitation adherence to home exercise programmes in patients with varying levels of self-efficacy. *Muscoskel Care*. 2018;16(1):233–237. https://doi.org/10.1002/msc.1194.
21. Ragettli MS, Flückiger B, Vienneau D, Domingo-Irigoyen S, Koschenz M, Röösli M. Vulnerability to heat-related mortality and the effect of prevention measures: a time-stratified case-crossover study in Switzerland. *Swiss Med Wkly*. 2024;154(10):3410. https://doi.org/10.57187/s.3418, 3410.
22. Dwyer IJ, Barry SJE, Megiddo I, White CJ. Evaluations of heat action plans for reducing the health impacts of extreme heat: methodological developments (2012–2021) and remaining challenges. *Int J Biometeorol*. 2022;66(9):1915–1927. https://doi.org/10.1007/s00484-022-02326-x.
23. Kemen J, Schäffer-Gemein S, Grünewald J, Kistemann T. Heat perception and coping strategies: a structured interview-based study of elderly people in cologne, Germany. *Int J Environ Res Publ Health*. 2021;18(14):7495. https://doi.org/10.3390/ijerph18147495.
24. Sheridan SC. A survey of public perception and response to heat warnings across four North American cities: an evaluation of municipal effectiveness. *Int J Biometeorol*. 2006;52:3–15. https://doi.org/10.1007/s00484-006-0052-9.
25. Abrahamson V, Wolf J, Lorenzoni I, et al. Perceptions of heatwave risks to health: interview-based study of older people in London and Norwich, UK. *J Public Health*. 2009;31(1):119–126. https://doi.org/10.1093/pubmed/fdn102.
26. WHO. Heat and health in the WHO european region: updated evidence for effective prevention. https://www.who.int/europe/publications/i/item/9789289055406; 2021. Accessed February 10, 2025.
27. Le plan national pour faire face aux vagues de chaleur. info.gouv.fr. Accessed February 10, 2025. https://www.info.gouv.fr/actualite/le-plan-national-pour-faire-face-aux-vagues-de-chaleur.
28. Emons WHM, Sijtsma K, Meijer RR. On the consistency of individual classification using short scales. *Psychol Methods*. 2007;12(1):105–120. https://doi.org/10.1037/1082-989X.12.1.105.
29. Niedergelassene Ärztinnen und Ärzte werden immer älter. Kassenärztliche Bundesvereinigung. https://gesundheitsdaten.kbv.de/cms/html/16397.php.