

BMJ Open Barriers to climate change and health research in India: a qualitative study

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ABSTRACT

Objectives Almost a quarter of the global burden of disease and mortalities is attributable to environmental causes, the magnitude of which is projected to increase in the near future. However, in many low- and middle-income settings, there remains a large gap in the synthesis of evidence on climate-sensitive health outcomes. In India, now the world's most populous country, little remains known about the impacts of climate change on various health outcomes. The objective of this study is to better understand the challenges faced in conducting climate change and health research in Puducherry, India.

Design and setting In this study, we employed key informant interviews to deepen the understanding of the perceived research barriers in Puducherry. The findings were analysed using data-driven qualitative thematic analysis to elaborate the major perceived barriers to conducting environmental health research.

Participants This study was conducted among 16 public health professionals, including medical researchers, and professionals involved in environmental policies and planning in Puducherry.

Results We identify three key barriers faced by public health professionals as key stakeholders, namely: (1) political and institutional barriers; (2) education and awareness barriers; and (3) technical research barriers. We show there is a need, from the professionals' perspective, to improve community and political awareness on climate change and health; strengthen technical research capacity and collaboration among researchers; and strengthen health surveillance, resource allocation and access to health data for research.

Conclusion Evidence informed policies and interventions are a key element in the adaptation response for countries. In the context of the paucity of data on environmental health from India, despite recognised climate change related health vulnerabilities, these findings could contribute to the development and improvement of relevant interventions conducive to a strong research environment.

INTRODUCTION

An ever-growing body of research has irrefutably shown the global health impacts of climate change through both direct and indirect exposure pathways.^{1,2} Multiple risk and vulnerability factors determine the population resilience and adaptive capacity, from

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study identifies crucial challenges faced in conducting environmental health research by public health professionals for the first time.
- ⇒ The findings draw on the experiences of respected experts who are well placed in the climate change and health sphere.
- ⇒ The sample was restricted to Puducherry district and not representative of the entire Union Territory of Puducherry, much less India as a whole.
- ⇒ The sample is restricted to the opinions of a selected group of experts and we could not include the experiences and perspectives of other public health professionals or stakeholders.

sociopolitical, demographic and biological factors to infrastructure, urban planning, health information systems and health workforce.^{2,3} Given the regional variations in climate systems, the health impacts of climate change differ between and within countries and communities, mediated by interconnected socioeconomic and environmental determinants of health.^{4,5} Non-communicable diseases, such as respiratory diseases, cardiovascular diseases (CVDs) and mental health conditions, have been recognised as growing climate-sensitive health outcomes, in addition to other communicable diseases like vector-borne and water-borne diseases and malnutrition.^{3,6}

With the rapid pace of climate change, the health impacts attributable to it are also projected to increase.⁷ Strengthening the adaptive capacity of countries is therefore an essential component of the climate change response.⁸ Timely public health interventions can do much to protect population health from the potential adverse health impacts of climate change.⁹ Low- and middle-income countries (LMICs), such as India, remain disproportionately affected by climate impacts, with a critical need to strengthen the healthcare response to climate impacts.^{10,11} One of the key steps in the regional or local



adaptation response is assessing the true burden of the health impacts within the population of that location.¹² However, owing to the complexity of the relationship between climate change and health, identifying and estimating this association remain one of the biggest global and environmental health challenges, especially in LMICs.¹¹

In India, the existing health and social disparities within the population make it one of the most vulnerable to climate change impacts, compounded by climatic diversity.^{13–16} There have been recent efforts from the Government of India to focus on climate change and health, as evinced by the recent addition of a health mission to the National Action Plan on Climate Change (NAPCC). This led to the formulation of the National Action Plan on Climate Change and Human Health (NAPCCHH) and the drive for State Action Plans for Climate Change and Human Health (SAPCCHH).^{17 18} The government recognises several diseases as climate sensitive in these official documents. However, public health engagement, action and research on health impacts of climate change are limited in India, especially given the magnitude of climate impacts to which it is vulnerable.^{19 20}

Medical and public health professionals, hereafter referred to as health professionals, play an important role in researching, managing and responding to climate change impacts on health. Along with being considered credible sources of information, these groups of professionals also have the capacity for scientific inquiries into the climate change attributable impacts of health.^{21–24} Globally, there is an acknowledged need to train health professionals to engage in, study and manage health impacts of climate change. There are few studies assessing stakeholder perceptions on climate change and health,^{14 25 26} and even fewer studies looking at specific barriers to research on this topic.^{27 28} Given the present gaps in this domain, especially in LMICs, it is particularly salient to better understand research barriers and needs, as perceived by health professionals.^{25–27 29}

The aim of this study is to understand some of the contextual barriers to environmental health action and research among two relevant professional groups in Puducherry, India. We focused our study on: (1) medical professionals, both in active research and practising; and (2) members of the Department of Science, Technology and Environment (DSTE) working on climate change in Puducherry. As this study is a part of a larger project on CVDs and climate change in India, we also highlighted

the specific challenges and barriers to conducting research on CVDs.

METHODS

Study setting

This study employed key informant interviews following a semistructured interview guide. The methods have been described in detail elsewhere. Briefly, the geographical focus of our study was Puducherry district, which lies on the south-eastern coast of India, with a population of 950 289, as per the Government of India 2011 Census.³⁰ Puducherry has one main State government run tertiary care hospital and medical college, along with several private clinics and primary care health centres. It is also home to the Central Government Jawaharlal Institute of Postgraduate Medical Education and Research, an ‘Institute of National Importance’ and tertiary care referral hospital. Within the DSTE, there also exists a specialised Puducherry Climate Change Cell with the aim to integrate knowledge about climate change and facilitate the NAPCC implementation, including the state specific Action Plan.³¹

Data collection and analysis

Sixteen semistructured interviews were conducted between January and March 2022 with participants from Puducherry. Fourteen interviews were conducted in-person and two were conducted virtually over Zoom. Using purposive sampling based on prior connections followed by snowball sampling, we invited medical professionals (research or practicing) and DSTE staff working on the Puducherry State Action Plan for Climate Change (hereon referred to as environmentalists). Interviews continued until information saturation was reached in the interviews or we had interviewed all the relevant target participants, as in the case of the DSTE staff. The full interview guide and framework with the main categories has been given in the online supplemental table S1.

Eleven of the participants had a medical background and were working as either practising physicians or researchers. Within the doctors, we mainly targeted cardiologists, emergency medicine or general medicine physicians who were involved in areas relevant to our study. The majority of the participants was male, with only three females, out of which only one had a medical background. Half of the participants were practising physicians, while

Table 1 Profile of participants interviewed in this study

Sector/background	n	Females (n)	Males (n)	Age range (years)	Range of experience (years)
Medicine (in-practice)	8	0	8	32–51	3–20
Research (medical)	3	1	2	40–44	11–20
Research (environment/governmental)	5	2	3	28–53	4–30

the other half were researchers. The participant profile is presented in [table 1](#) and further described in [Ref 32](#).

The interviews, conducted by S.S., lasted between 15 to 50 min and were audio recorded with informed consent using a voice recorder. Field notes taken to optimise the interview guide and note key topics. R.L. was a passive observer and facilitator for three interviews. We used an a priori developed interview guide with broad and open-ended questions to allow participants to freely bring up and discuss relevant topics. All interview recordings were assigned a number prior to transcription to ensure anonymity throughout the analysis process. Verbatim transcription and analysis was done using the MaxQDA software V.2018.1 (VERBI Software, Berlin, Germany) by S.S.

For the analysis, a combination of deductive and inductive thematic analysis was used as described by [Gale et al.](#)³³ Broad themes were developed based on the aim, framework and interview guide, as discussed below. During analysis, major themes were inductively developed for emerging topics, which we then clearly defined. After familiarisation with the transcripts, an initial codebook was developed from coding the three interviews with the richest data; the remaining interviews were indexed and coded further. The codes were classified into categories, subthemes and themes. The final analytical matrix included three themes. S.S. and T.L. independently validated the codebook with the three main interviews and agreed on the final framework matrix that considered all relevant codes. The matrix was then used to chart relevant

quotes supporting our findings and draw comparisons between participants.

The conceptual framework for climate change risk perceptions developed by [van Eck et al.](#)³⁴ and the framework for health inequalities proposed by [Rudolph et al.](#)³⁵ were used as a base for our analytical framework, shown in [figure 1](#). While there are three major themes, this paper focuses only on the theme of ‘Institutional determinants’. The findings from the two other themes have been elaborated elsewhere. Within the context of this paper, ‘institution’ is used as a broad term covering all governmental structures, including policy, education and occupation. We identify how these determinants can be perceived as barriers to environmental health research. The framework matrix with relevant themes and categories has been provided in online supplemental table S2. Additional supporting quotes have also been provided in the online supplemental material.

Ethical consideration

There was no prior relationship between the researchers and participants. Before the interview, the researcher went over the informed consent form, which was then signed by both parties. S.S., the main researcher, is an Indian PhD candidate supervised by a team of international experts based mainly in Switzerland. R.L. is also Indian national based in Puducherry. Additionally, all the quotes presented in this analysis have been assigned only by serial number to ensure anonymity.

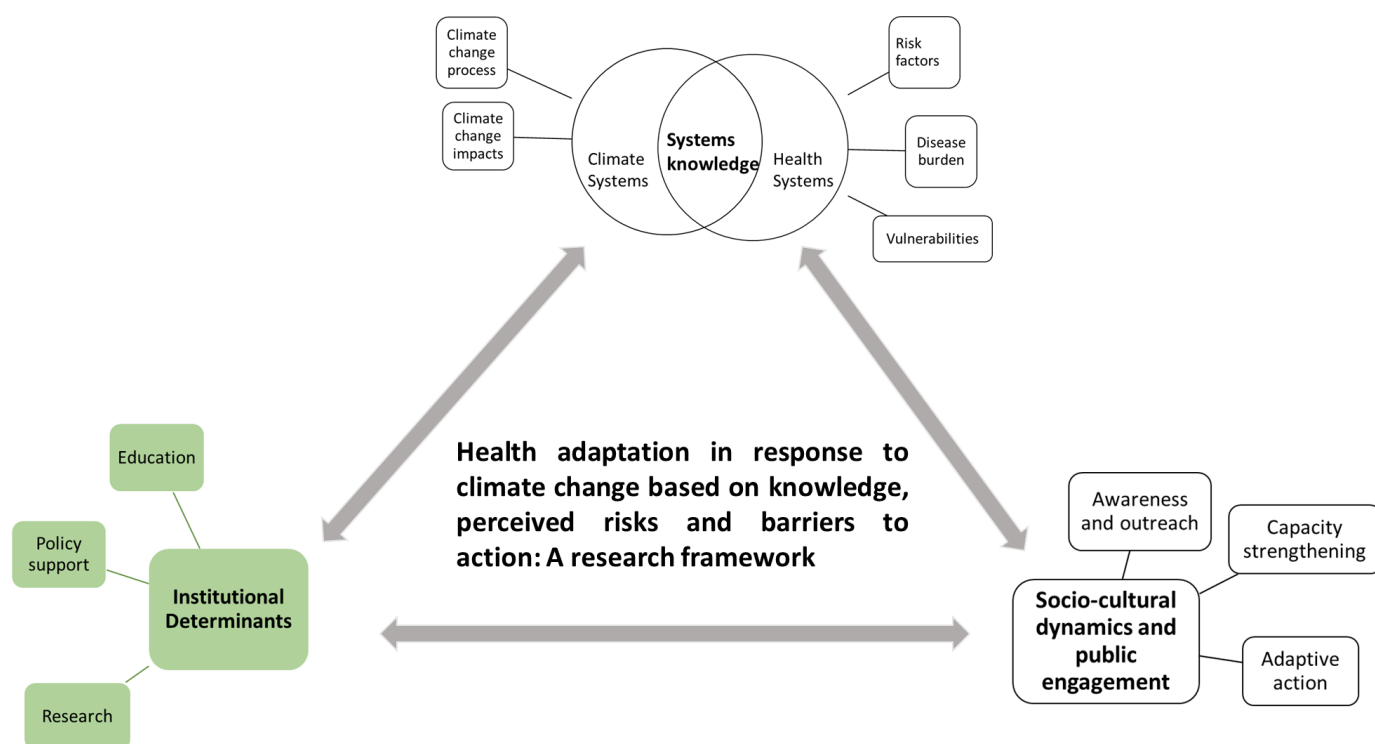


Figure 1 A framework for health adaptation action in the context of climate change based on level of knowledge, perceived health risks, policy and institutional support and public engagement. The circled part highlights the thematic areas we focus on in this work, namely institutional determinants and its challenges.

Institutional framework: knowledge on policies	<ul style="list-style-type: none"> Limited knowledge and awareness on climate change and health related policies
Political and institutional barriers	<ul style="list-style-type: none"> Disengaged leadership and low political prioritization of climate change and health Weak inter-departmental integration and co-ordination for climate change and health
Educational and informational barriers	<ul style="list-style-type: none"> Gaps in higher education curricula Weakness in inter-sectoral knowledge Scepticism and low awareness on non-conventional health impacts of climate change
Technical barriers and research	<ul style="list-style-type: none"> Insufficient resources and workforce dedicated to research Underdeveloped transdisciplinary research capacity Unavailability and limited access to quality data

Figure 2 An overview of the thematic framework and salient findings for the four themes explored in this paper. The four main themes are: (1) institutional framework: knowledge on policies; (2) political and institutional; (3) educational and informational; and (4) technical research barriers.

Patient and public involvement

As we employed a combination of purposive and snowball sampling, some participants were involved in helping us identify suitable participants to interview. Beyond that, no members of the public were involved in the design, conduct, reporting or dissemination plan of our research.

RESULTS

Overall, there are four main themes that emerged from this research, which are presented in [figure 2](#). We first report participants' knowledge regarding climate change and health policies, followed by their perceived institutional barriers to research, namely political, educational and technical barriers. As this study is part of a larger study examining climate change impacts on CVDs, we also highlight barriers specific to climate change and CVD research.

Institutional framework: knowledge on policies

Limited knowledge and awareness on climate change and health related policies

We found limited awareness among the participants about climate change and health-related policies, such as the NAPCC, NAPCCHH and SAPCCHH. Aside from the environmentalists, who worked on it, only three medical professionals who worked on one of the Action Plans

were aware of it. Four participants expressed belief about the non-inclusion of climate change in disease-specific policies and the lack of integrated climate change and health policies and guidelines.

Our country has different policy, environmental policy, health policy. But I have doubt whether health policy has any component of climate change. So, it needs to be incorporated in a health policy of national importance as well as the state, but currently, this element is not in place, that is my feeling. #8, Environmentalist.

One of the environmentalist also mentioned challenges in integrating climate change in development plans. These were thought to be made primarily from a socioeconomic development perspective, although there were ongoing efforts to include the economic co-benefits of climate change adaptation in the development plans.

The challenge is that the government sectoral officers are not aware of how the climate adaptations need to be integrated into their developmental plans. Because whenever they plan for a project, they plan it from the socioeconomic development perspective. #7, Environmentalist.

Political and institutional barriers

Disengaged leadership and low political prioritisation of climate change and health

Political leadership that did not consider health impacts of climate change as a pressing matter was perceived as one of the barriers to conducting research on the topic. Several participants mentioned how climate change was seen as future concern by policy-makers and the general public, rather than viewed as a cause for immediate concern. A few participants also mentioned the slim likelihood of decision-makers actually being aware of it. One participant described the issue as being 'not mainstream enough' to warrant focused work, contributing to the perceived low priority assigned to environmental health research.

Many participants felt that the governmental focus was inclined towards non-health impacts of climate change. The most pressing climate change impacts, which also influence research focus, were thought to be pollution, coastal sensitivity and natural resource depletion and degradation, especially in the context of Puducherry as a coastal region. Additionally, existing sectoral programmes already running were seen as a hindrance to focusing on climate change related programmes by one participant.

The problem is everybody has to understand at the level of the minister or the secretaries. So many programmes are there. Not only about climate change, other programmes are there so they do not focus much on (climate change) programmes... Actually, what I have seen for the past 2–3 years, they don't care much about climate. #1, Practicing physician/policy advisor.

Despite climate change being recognised as a health risk factor, there was a clear disconnect between on-paper government plans and practice when it came to environmental health research. The challenges India faces from other vulnerabilities, including unmet nutritional and economic needs, were perceived to outrank climate risks to health.

I'm an adviser to government of India on health related research. We did discuss a lot of things but we also touched upon climate and the effects of climate on health... That was considered as an important topic, but we didn't dwell much upon how to take it forward because there are more pressing problems. #15, Practicing physician/academic.

Weak interdepartmental integration and coordination for climate change and health

The compartmentalisation of topics within institutes or sectors was seen as a barrier to conducting interdisciplinary research by the participants. One participant discussed the newly formed Puducherry Climate Change and Health Action Plan (2022), which aims to bring together a multisectoral team, under the leadership of

the health ministry, to focus on health impacts of climate change.

However, apart from one participant, most others voiced a perceived need for an independent, coordinating body focused on environmental health, incorporating a research agenda. Partially, this was due to climate change being thought of an added responsibility for health professionals and vice versa for environmentalists, especially for those working in the government. As highlighted by a few participants, officials were likely to prioritise their primary work profile over the added responsibility of climate change and health research. Another concern in the existing scenario was intersectoral, collaborative research being dependant on higher officials being receptive to their junior employees researching a topic not entirely within the scope of their respective department.

Especially government departments, they are loaded with a lot of work. Today, an officer comes in, he has to do his own work, not the work that other departments asks us to do... #9, Environmentalist.

Several participants mentioned the Puducherry Climate Change cell created in response to address climate change impacts. However, despite that, one medical researcher mentioned the current difficulties in collaborating on climate change and health. Several participants also mentioned the need to improving coordination between the sectors, with a dedicated head of climate change and health.

Intersectoral body and there should be one decision maker. So now, everybody is like the leader in the particular sector, but if they need the support from other one, that coordination may be lacking... There won't be any one dedicated person for the climate change. So they will be in charge of multiple departments. For example, somebody's going to be in charge of immunization or the child health. So their priority will be child health obviously. #3, Medical doctor/academic.

Educational and informational barriers

Gaps in climate change and health in higher education curricula

One of the strongest emergent themes, referred to by most participants, was the need for environmental health education, either by incorporating climate change in the health curriculum or health impacts of climate change in the environmental curriculum in universities and schools. The prevalent feeling was the source of climate change and health literacy needs to be from multiple sources, with formal education being the most important one. Most participants also felt that at present there was a disconnect between environmental and health education, as a result of which there was a relatively low level of awareness on climate change impacts on health.

Education system need to be addressed from beginning... Even the medical college students who

are completing five years courses, I do not see any syllabus which contains impact on health by the climate change even though it is very important...my son is studying medical-medicine, but I guess I just go through the syllabus, but nothing is there. #8, Environmentalist.

All the environmentalists professed to never having specifically studied health impacts of climate change during the course of their education. On the other hand, the health professionals expressed incongruent views on climate change-health education. While one mentioned having studied climate sensitive diseases in medical school, another denied ever having been taught the link between climate change and various diseases.

Continuing education courses specific for health impacts of climate change were suggested by a few participants as potential options to bridge the gap between the environment and health. Two participants also suggested including short courses on this topic for all people working on topics related to climate change, health, adaptation and resilience.

Weakness in intersectoral information dissemination

Many of the participants mentioned having little to no awareness on climate change-health related research unless actively searching for it, pointing to the scope for improving related education and science dissemination, especially among the scientific community. Environmental risk factors were not commonly associated with health inherently, partially attributed the low scientific exposure on the topic.

CVDs were seen as a 'silent' disease, with many people are not trained to look for symptoms, much less correlate them to weather conditions, all suggesting the need for improved CVD literacy and awareness on the topic. On the other hand, many participants were open to changing their current schools of thought on risk factors for health to include climate change, conditional to being informed by global research on the topic.

If there is research or it's already proven in other countries, 'so this is a risk factor it is a good idea to add' but [before adding anything], I think some data or there should be some routine surveillance or monitoring system should be there. ... even within the medical circle, people may not be aware how much is the contribution of climate change to the heart disease or for any disease for that case... I don't think our administrators or even our clinicians are that much thinking about the impact of climate change, and [heart disease]. #3, Medical doctor/academic.

Scepticism and low awareness on non-conventional health impacts of climate change

As alluded to previously, health impacts of climate change are often not explicit, making it a challenge to research or focus the research agenda on for several reasons. One participant described how the slow pace of climate

impacts leads people to think it will not immediately affect health, unless the impacts are drastic.

...The problem has to become so severe, like you have air pollution in Delhi, then people will act. Climate change affects the life slowly it's not drastic... that is one of the reasons I feel. And slowly if you get some data and keep on generating awareness not only among the public, but also within the scientific community, then slowly things will be better. #3, Medical doctor/academic.

For researchers, an additional challenge of convincing funders or collaborators on the health impacts of climate change also emerged. One participant described the difficulty researchers had separating environmental risks from other common health risk factors. Scepticism when attempting to research health impacts of climate change was also encountered. Confounding from other risk factors and potential ecological bias was seen as the roots of this uncertainty.

Maybe for six, seven years, I have been trying to do some work on climate change and environmental health. Every time I write a proposal I'm criticized largely telling that "how is it going to work?... And one other problem I see with the research with climate change or any environmental thing, it's ecological effects. So people ask "how can you attribute this to only this, why not to this?," "Why not to lifestyle, why only to climate change?" So this direct relationship is not there. #4, Medical doctor/academic.

Diseases such as malaria, with historical links to stagnant water as breeding grounds, have been etched into public knowledge and further perpetrated through mass awareness campaigns, intervention programmes and research. The slow developing nature of CVDs and the prevalent categorisation of CVDs as solely lifestyle diseases was mentioned by many participants as potential barriers to research. One participant described how CVDs are commonly reduced to lifestyle diseases with the onus of risk management on the individual rather than a "willingness to see the invisible factors". The multifactorial nature of CVDs was thought to add to the difficulty of identifying climate attributable impacts. Another participant described how clinicians especially do not see the need to focus on environmental risk factors for CVDs, believing it ineffective in reducing the overall burden.

Non-communicable diseases, because we are not quantifying that and because of the long latent period of the incident, you're not able to quantify directly to environment or climate change. So definitely, hypertension, cardiovascular disease, all these probably diabetes also because of the changing food pattern, but I don't think—you cannot separate climate change from any of the health effects or any of the non-communicable diseases. Also related to

stress caused by climate change. #2, Medical doctor/academic.

The need for regional studies was also stressed on as there seemed likely to be a disconnect in comparing national-level or global-level problems with health impacts of climate change on a local level. Participants described the attitude of “this does not affect us” among the public when it came to climate change especially. A few participants expressed belief and hope that the temperature-CVD association was an upcoming topic of interest for the government and public alike.

Technical barriers to research

Insufficient resources and workforce dedicated to research

Resource allocation, especially financial, for climate change-health research was described as a barrier, especially by researchers. Along with inconsistent funding from the government, one of the problems mentioned was lack of adequate trained personnel. This was partially linked to the need to relieve the research expectations from already overburdened doctors. There was also a need to have trained personnel for digitalisation and categorisation of health data in order to create a digital state-level health database.

Some participants, referred to the low percentage of the annual budget of India allocated to health along with the need to increase this. One participant described funds earmarked for climate change-health research institutionally, along with optimism that this would lead to future research opportunities.

Yes, for recent years even ICMR (Indian Council of Medical Research) has called for proposals on this environment related, uh, this one. ICMR is one of the largest body which is for the research organisation as well as for the academic institutes like us. So, clearly, they are given a separate block of funding for climate change and [health]. That means the funds are available. #3, Medical doctor/academic.

However, this was countered by the notion that most of the funds are directed to central government institutes as opposed to smaller research institutes. A participant also alluded to misappropriation of research funding at an institutional level. Another participant spoke about the need to involve university students in research along with concern that most students do not get access to funding or research opportunities. There was a feeling that most students remain unaware of opportunities for funding or that funds do not ultimately reach the students aiming to conduct research. Another participant also described the prioritisation of more immediate health burdens and curative research as opposed to preventative research for the directing of funds or resources. This was supported by the opinion expressed by an environmentalist on climate change being viewed as a problem for the future as opposed to the present.

So though we focus on vaccination and other things, but still, the budget still flows more for the curative aspects rather than the preventive part. So for instance, the climate change is more of like, you prevent this—the future heart attacks or some other diseases. You have to focus on the prevention. #3, Medical doctor/academic.

Underdeveloped transdisciplinary research capacity

Alongside education, the need to build more technical capacity among researchers was also mentioned as one of the biggest challenges by participants. Despite a potential interest and willingness from researchers, the lack of training and expertise in climate change-health research was strongly expressed. This was tied in with the expressed desire for mentorship, both to facilitate increased awareness among the scientific and medical community as well as increased regional research on health impacts of climate change.

Yeah, more than research, I would tell it as people are aware and willing to do it, but here is more of capacity building... Let's say if I want to work on vector-borne disease, I know who to approach...but when it comes to climate change, that linking is absent. ... So actually, even if I'm interested and I want to work on it, there are a lot of hurdles which have to be crossed... So I have to be given an opportunity to work on it, or I feel somebody has to mentor me to work on it. So what we call as, starting trouble, you know is there. Once I think somebody starts, we will be going into it.... #4, Medical doctor/academic.

Some participants had the belief that larger research institutes or relevant ministries could be drafted to provide training to the smaller educational institutes or local government bodies. There was a sense of “duty” attached to studying all aspects of climate change impacts for the environmentalists in Puducherry tied in with a search for a starting point.

Research slowed by unavailability and limited access to quality data

Participants described critical gaps in monitoring, surveillance and database development, all of which were perceived to hamper research conduction, especially for health data. First, merging health data from the many healthcare facilities within Puducherry was seen as a challenge. There was an expressed need to bring together health data for the entire UT in a single system, including public and private healthcare facilities.

Second, some participants mentioned the state-level government health-monitoring database. However, participants described this as being limited to selected diseases from all the government run primary healthcare centres, with limited information on the private sector or secondary and tertiary care hospitals. A few participants described the lack of disease-specific categorisation

of health outcomes, making it an added challenge in conducting health-related research.

Third, participants also perceived private medical colleges and healthcare facilities as reluctant to share data with the government, with a felt need to enhance governmental efforts to work on the state-wide database. Fourth, on a related note, concerns about data quality were mentioned by several participants. Part of the reason for an unwillingness to share data by healthcare facilities was thought to be due to potentially inaccurate or poor quality data.

They're all afraid of like somebody will find a fault with that. So because they don't have manpower to look at the accurate or clean the data, okay, so somebody shares and later they find their mistake, and they will be answerable to the higher authority. So that's the usual reason we do not to share the data, the insecurity. #3, Medical doctor/academic.

Another challenge shared was the slow, ongoing effort to digitalise the data. Participants described as feeling unmotivated to start research at the cost of manually sorting through thousands of paper records, unless there was a way to guarantee research output. This was also relate to a challenge of medical professionals being overburdened with work.

There is not even a digitalization... Many hospital doesn't have digitalized MRD [medical records department]. For example, I was doing a study, retrospective study, collecting infective endocarditis data for past 10 years, there are more than 1000 files. How can I go through the 1000 files? It's not possible. #13, Practicing physician.

Surveillance of diseases was mentioned as ongoing work. Diabetes, hypertension, cervical cancer and other 'notifiable' diseases like infectious diseases were described as being under surveillance.

DISCUSSION

This research examined barriers faced in conducting climate change and health research by key stakeholders in Puducherry. The localised findings relatively remain relevant for India and can be extrapolated to other LMIC settings.²⁸ Four main themes emerged from this research, which are discussed below.

First, we found limited knowledge of relevant policies, especially among the participants with a medical background. In recent years, there have been a lot of strides taken in the Indian policy space with pertaining to climate change and health, such as the addition of the Health Pillar to the NAPCC and the subsequent development of the NAPCCHH and mandates for the development of the state-level action plans for climate change and health.^{17 18} Although the Health Pillar is a relatively recent addition (2015), there was still a substantial lack of awareness on the NAPCC as well as the health mission in

general, which we present as a key area for strengthening. Knowledge of such policies, especially if they can provide a framework to support-related research, is a useful tool to advance the research agenda on climate change and health.^{36 37} Health system vulnerabilities are already being seen in Puducherry and active knowledge of such policies can also be used by relevant stakeholders to develop resilience focused interventions. This includes communicating the severity of the problem to the policy-makers, who generally lack the political will to divert resources to non-apparent problems, alluded to by the participants in this study and identified in other studies.^{38 39}

Second, participants perceived climate change and health as a topic lacking political support and prioritisation. Most political efforts are thought to be focused on mitigation measures such as air pollution control, with little importance given to health adaptation and healthcare resilience. The participants believed that the health impacts of climate change were not a political priority or seen as urgent. Similar findings have been elucidated in other studies which also found public health leadership on climate change to be fragmented.^{27 40} Further efforts to inform the decision-makers on the importance of health adaptation might contribute to more evidence informed climate change and health policies.^{41 42} As an added justification for health cobenefits of mitigation can be introduced through multiple pathways, including air pollution, lifestyle modification, health surveillance or research programmes in development or related policies.^{43 44}

Participants also highlighted weaknesses in interdepartmental coordination for working on climate change and health. We found almost unanimous support for a separate intersectoral body focused specifically on climate change and health. Methodological challenges in the light of limited technical knowledge and adequate intersectoral coordination and support for transdisciplinary capacity that we found have also been reported elsewhere.^{29 45} A recent study on the knowledge, attitudes and practices related to climate change and health among the Indian health workforce found intermediate or delayed health impacts of climate change less commonly identified.²⁶ This could also support the development of regional, national or even international research networks facilitating knowledge sharing and transfer, including research methodology support.²⁹

The siloed operations of 'health' and 'climate change' were also seen as a research barrier. This was partially due to the unclear division of responsibilities and fragmented institutional focus, as also seen in other studies.^{29 40 46} A study examining the challenges for the Californian public health sector in climate change found the compartmentalisation and lack of intersectoral coordination to limit work on intersectoral issues such as climate change and health.²⁷ Our findings point to the need to have regular national level conferences or improved science dissemination systems to communicate climate adaptation related research or plans between and across sectors.

Third, participants perceived gaps in formal education and training on climate change and health. Our respondents had varied views regarding education on climate change or its health impacts; however, the need to improve this was clearly described by participants in this study. The need for strengthening capacity and education has been a common finding in several other studies. Globally, there is a critical gap and scope for improvement in the education on health impacts of climate change, especially for medical practitioners.^{25 27 47–54} A study comparing medical curriculums across the world found inconsistencies between environmental changes, health and community needs, with Indian and Chinese students especially having a gap in the inclusion of planetary health in medical schools.⁵⁰ The inclusion of planetary health from an early stage for medical students leads to a more active role of physicians in educating their patients about climate risks.^{50 55} However, there is a need to validate the results in future studies given the inconsistencies in the views we found on climate change-health education. The emphasis on cure rather than prevention, which has shown to reduce long-term healthcare costs, could support the need for Puducherry to focus on the preventative aspects, largely through education and awareness.²⁴ We also found scepticism and low awareness on the non-conventional health impacts of climate change, such as CVDs. These health impacts were thought to be viewed as ‘invisible’ compared with more conventional or immediate impacts, such as air pollution or extreme events. This is also a commonly identified challenge to climate change and health research, accompanied by insufficient education about climate systems during the course of school or university education.^{26 56}

Fourth, technical research barriers we found included insufficient data, capacity, human and financial resources. Data barriers remain common challenges in public health research, despite efforts to facilitate improvements.^{57 58} As Puducherry has the advantage of a relatively small size and well-connected healthcare facilities, efforts need to be taken to improve a central, disease-specific data collection system, incorporating all the healthcare facilities in the state.⁵⁹ Facilitating training to build local data analysis expertise and capacity would contribute to more region specific research on the topic.⁶⁰ As was also made apparent in this study, other studies have shown that health impacts of climate change are a relatively new concept and not inherently associated with climate, potentially explaining the uncertainties and scepticism expressed by our participants, especially for diseases that do not warrant a visit to the doctor.^{61 62} On the positive side, the expressed desire of participants to learn more about it and make changes to the healthcare system and policies based on robust, conclusive evidence implies a willingness to adapt and implement changes in how the region tackles health impacts of climate change.^{49 63} Resource and funding constraints are one of the most common barriers to public health research, especially in LMICs and there remains a critical need to address this gap.⁶⁴

At present, little is known on CVD impacts of climate change in India. Our related study from Puducherry found a high attributable burden of non-optimal temperature to CVD mortality, suggesting a need for similar studies from around the country.^{65 66} The CVD-specific challenges we identified here are comparable to the general health challenges. Awareness among the medical community on the environmental risk factors of CVDs will be instrumental in furthering this research agenda, while awareness among policy-makers will help raise the political prioritisation of CVD impacts of climate change.^{24 67 68}

Limitations

First, the sample was restricted to Puducherry district and not representative of the entire Union Territory of Puducherry, much less India as a whole, although the projected population for Puducherry is 1.25 million in 2021, comparable to a few smaller countries or global regions.⁶⁹ The results might thus only reflect the studied context and participants. Second, while we chose to focus on the medical community and DSTE representatives working on climate change, we did not include the experiences and perspectives of other public health professionals or stakeholders. Third, we do not highlight the opportunities for increasing research on climate change and health as many of these are very often interconnected with barriers. However, we do discuss potential recommendations given by stakeholders. Nonetheless, the results of this study could be useful for the research community and policy-makers alike to strengthen climate change and health research and engagement.

CONCLUSION

There is a great need to fill the gap in research on the impacts of climate change on various health outcomes in India, especially in light of the vulnerabilities it faces. By highlighting some crucial barriers to environmental health research faced by relevant professionals, we present potential intervention points for consideration. Insufficient awareness on health impacts of climate change and perceived need to improve research capacity through collaborative work; and challenges in data availability emerged as the largest barriers to conducting research on this topic in Puducherry. We outlined the gaps and scope for addressing these through improved policy awareness; informed leadership and evidence informed climate change and health policies; research capacity strengthening and transdisciplinary research and communication network; improved education on climate change and health on all levels; and addressing data barriers in climate change through improved monitoring and evaluation systems. The key findings could contribute to supporting and strengthening evidence-informed climate resilient healthcare systems. In addition, it would also serve to inform and strengthen the

research and institutional support for environmental health research in the future both in India and globally.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the Institute Ethics Committee (Human Studies) of the Indira Gandhi Medical College and Research Institute (A Government of Puducherry Institution); No. 318/IEC-31/IGM&RI/PP/2021 and by the Ethics Committee Northwest and Central Switzerland; Statement ID- AO_2020_00034. The methodology used in this project abided by the principles laid out in the Declaration of Helsinki and the Consolidated criteria for Reporting Qualitative research checklist. All participants were verbally explained the project and its objectives as well as being provided information sheets. All participants were made aware of their right to refuse participation at any point prior to publication of the study. Signed informed consent was obtained from all participants prior to the interviews, with participants retaining one copy.

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Supplementary material

1. Interview questions guide for medical professionals and members of the Department of Science, Technology and Environment (DSTE) working on the Puducherry State Adaptation plan

COMMON QUESTIONS

Table S1: Common interview question guide based on the participant group.

Target group	Themes	Aims	Questions
COMMON	Participant information	To get the basic demographic and professional information about the participant	<ol style="list-style-type: none"> 1. Age 2. Nationality 3. Place of residence 4. Educational background and speciality 5. Occupation 6. Years in occupation 7. Professional experience related to climate change and/or health
	Background knowledge-climate change	To establish level of knowledge about climate change with 'warm up' questions	<ol style="list-style-type: none"> 1. What comes to mind when you think of climate change? 2. What do you think are physical manifestations of climate change? 3. Have you experienced or been aware of any climate change events in the past few years? 4. What, according you, are the most common consequences of climate change?- Which aspects of life do they affect most severely?
	Climate change and health, climate change and CVDs	To establish knowledge/ awareness about climate change and health and climate change and CVDs	<ol style="list-style-type: none"> 1. Have you ever thought about the health impacts of climate change? 2. What aspects of human health do you think climate change will have the biggest impact on? 3. Are you aware about the impacts of climate change on NCDs such as cardiovascular diseases? <ol style="list-style-type: none"> 3.1. If yes to above question, what do you know about it? How do you know about it (eg

			through research or through professional experience?)
	Policies and plans	To establish knowledge and awareness levels about policies and plans on the issue of climate change and health	<ol style="list-style-type: none"> 1. Are you aware or have you been part of any policies/plans/programs on the issue of climate change and health? 2. If yes, what were/are they? -What diseases or health topic did it focus on? What was the work done (aim)? Do you think it was successful and beneficial? 3. Do you know any plans/programs specifically targeting climate change and heart diseases? (can be from any sector). 4. Do you know about the national/state climate change adaptation plan? 5. If yes, do you know of the role health plays in it?
	Challenges and outlook	To understand challenged faced, potential solutions and planned changes	<ol style="list-style-type: none"> 1. Are you aware of any upcoming or recent changes to the health adaptation plans or any other relevant policy that target climate change and health? 2. Do you know any policies which can be used to increase awareness and research on the impact of climate change on CVDs in India? 3. According to you, what are the biggest drawbacks and challenges faced- why do you think health or NCD impacts of climate change are not a priority? 4. What can be done to change that? 5. Can you think of some measures to mitigate the impacts of climate change? <ul style="list-style-type: none"> - Your contribution to mitigating the impact, whether it's individual or you think it should

			<p>be more at a governmental level?</p> <ul style="list-style-type: none"> - Examples can be green healthcare facilities etc
Medical Professionals	Climate change and health-medical experience	To understand perceptions on the extent to which climate/temperature affects patient health	<ol style="list-style-type: none"> 1. Do you think climate, especially temperature affects health based on hospital admissions and mortality? 2. Can you explain what you have observed (eg, more patients on particularly hot days). 3. Which diseases have you observed to be the most sensitive to climate/temperature? 4. Based on your day to day observations, do you see an association between temperature and CVDs? 5. Do you think we will see an increase in the CVD deaths attributable to temperature in the future?
	Population vulnerability	To understand views on how different people are affected based on demography	<ol style="list-style-type: none"> 1. Which people have you observed to be the most vulnerable to temperature? (eg, age, gender, occupation, SE status etc) 2. Do you see a big gender difference in CVD patients with and without the influence on external temperatures? 3. Have you observed an association between age/gender and temperatures? For example, are a certain group of people more susceptible to heat or cold? 4. Do the public and private sectors work together during disasters? <ul style="list-style-type: none"> - How is the communication, facility and equipment sharing?
	Education and training	To understand level of training and awareness among	<ol style="list-style-type: none"> 1. Have you ever been explicitly trained, either during medical school or

		doctors on climate sensitive diseases	<p>professionally, on climate sensitive diseases?</p> <ol style="list-style-type: none"> If yes, where did the course take place (India or abroad, college or professional) and what did it cover (broadly) If yes, did the course include CVDs? Did it include gender differences in terms of symptoms? Do you think such a course is needed or would be beneficial?
	Measures to be taken	To discuss possible measures to be taken to increase awareness and preparedness on climate sensitive diseases	<ol style="list-style-type: none"> Assuming that we will be seeing an increase in CVD mortalities attributable to temperature in the future, what measures do you think can be taken to prepare and adapt to it? <ul style="list-style-type: none"> In hospitals, in medical schools, Give an example..early warning systems, emergency cardio bays in hospitals, awareness drives etc What policy measures do you feel would benefit with the issue of climate sensitive diseases? For CVDs?
Health department (policy makers, ministerial representatives)	Current policies	To understand current health policies and whether climate change is included in them- include CVD policies and training	<ol style="list-style-type: none"> Do any of the current health policies include climate change? Are there any specific policies on climate sensitive diseases? <ul style="list-style-type: none"> Guidelines for disasters Guidelines for heat If yes, do any policies include NCDs or CVDs specifically?
	Challenges and outlook	To understand current challenges and future plans	<ol style="list-style-type: none"> The national adaptation plan recently added health as one of its climate change missions- why do you think this was not always a priority?

			<ol style="list-style-type: none"> 2. FOR PUDUCHERRY- Why is there no health mission in the state adaptation plan? Are there plans to include it? If yes, what diseases will be focused on? 3. Are any activities being planned around climate sensitive diseases especially CVDs? <ul style="list-style-type: none"> - Awareness programs - Education and training in medical schools? 4. Are there any plans to develop and expand heat action plans nationally? (eg. Ahmedabad heat action plan) 5. Which diseases will be a priority area for climate sensitivity in terms of policy and research? 6. Is there any research or study being conducted on the health impacts of climate change? Are there any plans to do so? 7. CVD effects and most other effects of climate change affect vulnerable populations most-how do you plan to address some of these challenges? <ul style="list-style-type: none"> - Rural vs urban exposures and requirements differ. Are there plans that specifically target different populations? - What about different communities? Do you feel different communities have different needs to protect themselves against the climate? Can you elaborate? - What about different SE groups?
Department of Science, Technology and Environment	Current policies	To understand the development process of the adaptation plan and how health is	<ol style="list-style-type: none"> 1. The adaptation plan has recently added a health mission, but it does not have a comprehensive list and guidelines for climate

		included in current policies	<p>sensitive disease management?</p> <ol style="list-style-type: none"> 2. The adaptation plan is an intersectional plan with involvement from many departments. Does the steering committee have regular meetings to review and stay prepared, if so how often? <ul style="list-style-type: none"> - Review meetings? - Do you make changes to the plan based on new evidence or incidences? 3. Is there a reason that NCDs such as CVDs, despite having a huge burden of disease are not explicitly included and researched in terms of climate attributable burden? 4. What plans/programs/campaigns are presently ongoing that deal with climate-health adaptation? Are there any specific to CVDs? 5. Can you tell me about any plans or policies that have been previously implemented on the topic of climate sensitive diseases? <ul style="list-style-type: none"> - Were they successful and effective? - What is the present status of these? - What were the biggest challenges faced? 6. CVD effects and most other effects of climate change affect vulnerable populations most-how do you plan to address some of these challenges? <ul style="list-style-type: none"> - Rural vs urban exposures and requirements differ. Are there plans that specifically target different populations?
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			<ul style="list-style-type: none"> - What about different communities? Do you feel different communities have different needs to protect themselves against the climate? Can you elaborate? - What about different SE groups?
	Challenges and outlook	To understand challenges faced and future plans	<ol style="list-style-type: none"> 1. What is the biggest challenge in formulating and implementing climate sensitive disease policies or policies related to climate impacts on health? 2. Are there any plans to include NCDs and CVDs as a separate component of climate sensitive diseases? 3. Are there research projects planned on this topic to inform priority setting and policy formulation? 4. What measures do you think need to be taken to help formulate better , more comprehensive climate change policies that are informed by health research?
			<p>The adaptation plan is an intersectional plan with involvement from many departments. Does the steering committee have regular meetings to review and stay prepared, if so how often?</p> <ol style="list-style-type: none"> 1. Review meetings? 2. Do you make changes to the plan based on new evidence or incidences? 3.
EDUCATION- either department or medical college educators	Current practices	To understand current medical curriculum and whether climate change is included in it	<ol style="list-style-type: none"> 4. Does the current medical school curriculum include climate change with respect to diseases that are sensitive to it? 5. Do you feel this needs to be taught?

			<ol style="list-style-type: none"> 6. Do you think temperature affects diseases? 7. What diseases do you think are most sensitive to climate change that need to be included in the curriculum? 8. If yes to above questions, does it include gender differences?
	Challenges and outlook	To understand challenges in teaching students about climate change and plans for future along with suggestions	<ol style="list-style-type: none"> 1. Are there any plans to include climate sensitive diseases in the curriculum? 2. What other measures do you think can be taken with respect to the training of medical workers to reduce the burden of climate sensitive diseases? <ul style="list-style-type: none"> - Ex, emergency bays, more ambulances or staff during days of particular temperature etc

2. Framework with themes and relevant categories

Table S2: Structural codes and framework matrix

Theme	Sub-theme	Categories
Climate change and health: systems knowledge and perceptions	Climate change as an acute and growing problem for India	
	Domino effect on impacts of climate change ultimately converges at health	
Role of institutions	Political and institutional barriers	Limited knowledge and awareness on climate change and health related policies
		Disengaged leadership and low political prioritization of climate change and health
		Weak inter-departmental integration and co-ordination for climate change and health

	Educational and informational barriers	Gaps in climate change and health in higher education curricula
		Need to strengthen inter-sectoral information dissemination
		Scepticism and low awareness on non-conventional health impacts of climate change
	Technical barriers to research	Insufficient resources and workforce dedicated to research
		Underdeveloped transdisciplinary research capacity
		Research slowed by availability and access to quality data
Socio-cultural dynamics, outreach and engagement	Need for alternate solutions, targeted campaigns and programs at all levels	
	Role of experts and famous personalities in awareness building	
	Climate informed health policies and seasonal workplace guidelines	
	Integrating climate change in the curriculum and continuing educational courses	

3. Additional supporting quotes

- i. Institutional framework: Limited knowledge and awareness on climate change and health related policies

“Priority areas means, uh, for example, climate change in the health department, there is no clear cut guidelines is there. There is no clear cut guidelines, there is no clear cut programs are not there regarding climate and health.”#16, Practicing physician

- ii. Institutional barriers: Disengaged leadership and climate change not seen as immediate health concern

“When we practice medicine, because we are more concerned with treating the patient rather than you know, going and finding out the cause and prevent the incident in happening. So there the problem is a disconnect between, uh, what is happening (and) the preventive aspects, we were not able to quantify, especially in our setup here in India.” #2, Medical doctor/academic

- iii. Institutional barriers: Integration of climate change-health as a separate, inter-departmental body

“Because one thing is, it is not about criticizing some other officer, it is like they have to do their work, not other department's work. So then the head should accept that they have to spare their times [for] this climate change work.. It depends on who the nodal officer is, who the higher officer is, and who the head of the bureaucracy is. So when people are okay with working on this, things would be fine. But people don't care things will be the other way. So, in short, I would say that it has to come from the top down approach.” #9, Environmentalist

- iv. Technical barriers: Insufficient resources and workforce dedicated to research

““The UT of Puducherry, we do not have much data. So we need to focus and we need manpower. We do not have the funding also it's a problem now. Sometimes they provide funds; sometimes they do not give that adequate funds.” #1, Practicing physician/policy advisor.

- v. Technical barriers: Availability and access to quality data slowing down research progress

“The state government has the, uh, database. We may not have a line list. So without line list we cannot call it as database, but they will have each primary health center how many patients with NCDs, diabetes, hypertension, stroke, they have the data. So that is there. But, uh, I think last two to three years only they started screening households for diabetes, hypertension and cervical cancer, but not specifically targeting high risk groups. For the private side, we don't have the database on how many are-It's not like a tuberculosis program. We have the line list, total line list of whether they are part of the public health

program or the private. So there we will have a database of patients but not for the non-communicable diseases.” #3, Medical doctor/academic

“Puducherry as so many medical colleges, but all of them do not supply data to the government. They may have their own data. That’s the problem: actually we have to integrate everyone” #1, Practicing physician/policy advisor.

- vi. Technical barriers: Need for more resources and workforce dedicated to research

“One is like, if you know, India should actually allocate more funds from the GDP towards the health sector. Actually, if you speak, there is not much of research work going on. Probably in the last like three to four years, it might have picked up... Most of the Indian government funding is going to the Central Institutes. For example, if you go to any government, hospital, state run government hospital, they don't have any separate data entry and don't have any separate research. You should bringing the students into the studies, which are happening only in the institutions not in the state run hospitals. Because they actually- many funds are- see now also funds are coming to state. They're giving directly to the institutes. But no one knows where the fund goes. Ultimately, it doesn't reach the students. It disappears at the level of consultants.”#14, Practicing cardiologist

- vii. Technical barriers: Scepticism and low awareness on non-explicit health impacts of climate change

“When it comes to non communicable disease, one is this relationship it's also is not synced into us...Once people know that this is going to happen, then actually there's a percolation of knowledge that 'climate change is affecting this, and you have to look for it.' But as of now, if I go and tell a clinician that climate change is affecting NCDs, or cardiovascular disease, they will be laughing at me. They tell it's the lifestyle diseases, which is affecting them. So I'll be a fool actually for talking to them...Even if I work on it and show, if I don't have expertise, they're going to snub me off tell that "no, it's only a remote, it could be this, it could be a confounding, it could be a bias.” #4, Medical doctor/academic

- viii. Technical barriers: Need for transdisciplinary research capacity

“One important thing that I would like to register is we ourselves need to participate in certain workshops which are done by certain other people, for

example, DST [Department of Science and Technology] from New Delhi. For example, in the last two years, the only technical work that we've done for our city, is like this vulnerability assessment. But...we in our cell, or even officials here, we are not pre-sensitized with all these things. So only when we take up learnings from outside, we can execute that for our city, for our state.” #9, Environmentalist

ix. Specific challenges in studying the cardiovascular impacts of climate change

“But non communicable disease, like cardiovascular disease, no one tells complaints noone also correlates all those things. They just think of diabetes, hypertension, cholesterol, and all these things maybe because of the elevated sugar, and the BP it might have got the ,uh, cardiac complaint. Now one doesn't correlates all the things since he has gone in the rainy-rain or since he has got the cold. Noone correlates. And I think we should also think about all those things.” #13, Practicing physician

“In hospitals, even this point of you know, we are expecting more of even this trend of increased changing of our climate and (that) has to be made aware to people. (When we were discussing on the topic of climate change) when it went to the clinicians, they're like, "how is it going to help me? It's not going to help me". They are very careful with the infectious disease...”#4, Medical doctor/academic