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Dengue control in the context of climate change: Views from health professionals in different geographic regions of China

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ABSTRACT

Background: Dengue is a significant climate-sensitive disease. Public health professionals play an important role in prevention and control of the disease. This study aimed to explore dengue control and prevention in the context of climate change in China.
Methods: A cross-sectional survey was conducted among 630 public health professionals in 2015. Descriptive analysis and logistic regression were performed.
Results: More than 80% of participants from southwest and central China believed climate change would affect dengue. However, participants from northeast China were less likely to believe so (65%). Sixty-nine percent of participants in Yunnan perceived that dengue had emerged/re-emerged in recent years, compared with 40.6% in Henan and 23.8% in Liaoning. Less than 60% of participants thought current prevention and control programs had been effective. Participants believed mosquitoes in high abundance, imported cases and climate change were main risk factors for dengue in China.
Conclusion: There were varying views of dengue in China. Professionals in areas susceptible to dengue were more likely to be concerned about climate change and dengue. Current prevention and control strategies need to be improved. Providing more information for staff in lower levels of Centers for Disease Control and Prevention may help in containing a possible increase of dengue.

Introduction

Climate change is one of the biggest health challenges this century [1]. In response to changes in temperature, precipitation and humidity, climate-sensitive diseases have emerged and re-emerged in new areas in recent decades [2]. Dengue fever is a notable climate-sensitive vector-borne viral disease which places 3.9 billion people at risk globally [3]. In the last 40 years, dengue has become a serious public health challenge in China. Historically, there were no dengue cases reported in China until 1977, then in 1978, a dengue outbreak occurred in Foshan city, Guangdong Province in south China, which resulted in 22,122 cases, and 14 deaths [4]. Dengue has since been frequently reported in China, especially in south China, such as Guangdong, Guangxi and Yunnan Provinces. In 2014 there was an unprecedented dengue outbreak with 47,056 cases reported in China [5]. *Aedes albopictus* and *Aedes aegypti* mosquitoes are the main vectors of the dengue virus, with the former acting as the primary vector in China [5,6]. DENV-1 is the predominant serotype circulating in the country [7]. China, has a population of 1.3 billion across several different climatic zones

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— from north China in the cold temperate zone, to central China in the temperate zone, and south China in the tropical and subtropical zone. The highest risk areas of dengue are in the south and southwest parts of China, where the hot and humid weather provides an ideal environment for the survival and reproduction of dengue vectors [8]. The incidence decreases with increasing latitude such that there are relatively fewer dengue cases reported in the northeast [7]. However, the winters are becoming milder in the central and northern areas due to climate change [9,10]. This may in turn enhance dengue transmission by allowing mosquito vector survival in previously unsuitable areas, by lengthening the active mosquito season, and/or by shortening the extrinsic incubation period of the virus.

In China, the Centers for Disease Control and Prevention (CDC) work to protect and improve population health and safety [11]. One of the significant duties of the CDCs is to control and prevent infectious diseases [11]. The administrative system of China's CDCs consists of four levels: county-, prefectural-, provincial- and national-level CDC.

A previous study in Guangdong Province has shown that 98.4% of public health professionals perceived that dengue had emerged or re-emerged in recent years, and 96.1% of the participants believed climate change would influence dengue fever [12]. However, the study was conducted in one province only, whereas dengue cases have now been reported in most parts of China [7]. Therefore, it is necessary to draw a broader picture of dengue control and prevention in different geographical areas of China. This is particularly important for the regions that have lower dengue transmission currently but may face a greater likelihood of increasing dengue transmission in future. We therefore aim in this study to explore health professionals' perceptions about climate change and dengue transmission in China with different geographic characteristics and dengue incidence rates varying from low in the northeast to high in the southwest.

Methods

This study employed a cross-sectional survey among public health professionals in 2015 to explore dengue control and prevention in the face of climate change.

Study sites

Three provinces were selected in this study (Fig. 1): Yunnan Province in southwest China with a high incidence of dengue — 3.85 cases per 100,000 in 2015 [13]; Henan Province in central China with less risk of dengue infections, and the incidence rate is 0.04 cases per 100,000 in 2013 [14]; and Liaoning Province in northeast China with a low incidence of dengue — 0.01 cases per 100,000 in 2015 [13].

Yunnan Province is located in southwest China and is bordered by dengue-endemic countries. Imported cases in Yunnan accounted for 28.8% of national imported cases over the period 2005–2014 [7]. Yunnan has a tropical and sub-tropical highland monsoonal climate [15], which is conducive to dengue transmission.

Henan Province is located in central China. It has a temperate climate with four distinct seasons [16]. It is the northernmost province with local dengue transmission [17]. The local climate during the warm season is suitable for the survival of the dengue vectors [5].

Liaoning Province is located in northeast China and is the coolest of the three provinces with a temperate continental monsoonal climate and four distinctive seasons [18]. It is a low-risk area for dengue transmission in China.

Study participants

The study participants were CDC public health professionals whose roles pertain to disease control and prevention, vector control, environmental health, medical laboratory diagnostics and emergency response. In this study, 11 CDCs were involved: three provincial CDCs, one prefectural CDC and one county CDC in Yunnan, two prefectural CDCs and one county CDC in Henan, and one prefectural CDC and two county CDCs in Liaoning (Fig. 1). These provinces and CDCs were selected with consideration of advice from experts at the China National CDC, where it was thought that these participants could provide informed responses about their experience with dengue in China.

Questionnaire instrument

The questionnaire instrument was developed following discussions with academics and health professionals, and after a review of relevant literature that had previously examined health professionals' perceptions of infectious diseases in the context of climate change [19–21]. The full questionnaire has been described previously [22,23], this study reports information relating to dengue control, and the relevant section of the questionnaire instrument is included in Supplementary Appendix A.

Data collection

To facilitate the distribution of questionnaires and maximize response rates, investigators made initial contact by telephone with key informants from the sampled CDCs. These key informants were notified of the survey's aim and main content, and invited their colleagues to participate in the survey. In total, 666 questionnaires were distributed and collected in 2015. However, due to missing data, 36 of these questionnaires were eliminated leaving 630 valid questionnaires. Therefore, the overall response rate for this study was 94.6%.

Statistical analysis

Using EpiData 3.1 software [24], a database was developed and the collected questionnaires were entered. The data were then transferred to Stata 14.2 [25] for statistical analysis. Descriptive analysis was conducted using simple frequency calculations to describe the demographic characteristics of the public health professionals. The association between demographic variables and perception variables were assessed using Chi-square test or Fisher's exact tests if expected cell frequencies were less than or equal to five [20]. Logistic regression was used to determine the association between binary responses and demographic variables. The binary responses were "Yes" and "No/Unsure", which were generated based on the response choices "Agree strongly", "Agree somewhat", "Unsure", "Disagree somewhat" and "Disagree strongly". The positive responses "Agree strongly", and "Agree somewhat" were coded "Yes", while non-positive responses including the negative responses "Disagree somewhat", "Disagree strongly" and neutral response "Unsure", were coded "No/Unsure". The neutral response was re-categorized into "No/Unsure" with the consideration of Chinese cultural factors around refusal [26]. The univariate analysis was conducted between binary responses and each demographic variable. In the final model, the multivariate analysis was conducted between binary responses and the selected demographic variables having a significant univariate test at the level of 0.2. The odds ratio (OR) with 95% confidence intervals (CI) and p-value from regression models were calculated. Data were analyzed with a two-sided test, and p-values less than 0.05 were considered statistically significant. In addition, an open-ended question was used to

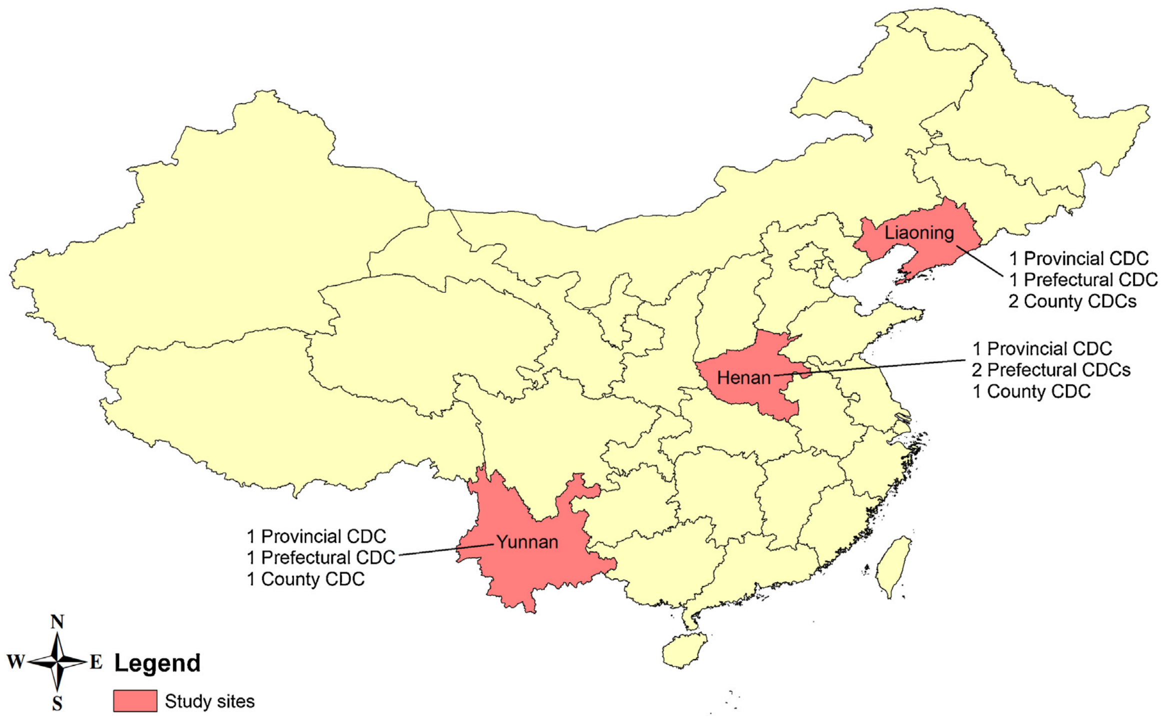

Fig. 1. Geographical location of study sites in China.

explore public health professionals' perceptions of potential main risk factors for dengue.

Ethics approval

The study was approved by the ethics committees of the University of Adelaide (approval no. HS-2013-052), the University of South Australia (approval no. 0000032268), Monash University (approval no. CF13/3263-2013001642), Anhui Medical University (approval no. 2013007) and the Chinese Center for Disease Control and Prevention (approval no. ICDC-2013002).

Results

Demographic characteristics

Table 1 shows the demographics of the surveyed public health professionals in China. There were 172 participants from Yunnan CDCs, 231 from Henan CDCs, and 227 from Liaoning CDCs. The majority (56.2%) of participants were aged less than 40 years, more than half (54.7%) were female. Most participants (46.6%) were well educated holding an undergraduate degree and 23.4% holding a postgraduate qualification. There were 53.9% of participants working in Provincial-level CDCs, and 46.1% working in Prefectural/County-level CDCs. More than half the participants (55.1%) had been employed at the CDC for more than ten years. There were 30.0% employed at junior level, 41.3% at intermediate level, and 18.4% at senior level.

Table 1
Public health professionals' demographic characteristics (N = 630).

Characteristics	Number	Percent (%)
Site		
Yunnan	172	27.3
Henan	231	36.7
Liaoning	227	36.0
Age group (years)		
20–39	338	56.2
≥40	263	43.8
Gender		
Male	280	45.3
Female	338	54.7
Educational level		
Below undergraduate degree	183	30.0
Undergraduate degree	285	46.6
Postgraduate degree	143	23.4
Levels of CDC		
Provincial	335	53.9
Prefectural/County	287	46.1
Length of employment (years)		
Less than ten years	248	44.9
Ten years and more	304	55.1
Professional level		
Junior	189	30.0
Intermediate	260	41.3
Senior	116	18.4
Other	65	10.3

The total number may not be equal to 630 for all items as some questions were not answered.

Perceptions of the impact of climate change on dengue fever transmission

The majority thought that climate change would have an influence on vector-borne diseases and dengue fever (Table 2). Specifically, nearly 90% of participants in Yunnan and more than 80% of participants in Henan believed climate change would impact on vector-borne diseases and dengue, while there were significantly fewer (65%) participants in Liaoning who indicated so. Multiple logistic regression showed there was a significant association between sites and perceptions of climate change impacting on vector-borne diseases and dengue. Specifically, compared with participants from Liaoning, those from Henan and Yunnan were 2.8 and 5.4 times more likely to indicate climate change impacting on vector-borne diseases, respectively, and 2.3 and 3.5 times more likely to indicate climate change impacting on dengue (see Supplementary table S1).

Table 2
Public health professionals' perceptions of climate change impacting on vector-borne diseases and dengue fever.

Climate change		Will have an influence on vector-borne diseases	Statistics	P	Will have an influence on dengue fever	Statistics	P
Yunnan	Yes	108 (89.3)			149 (88.2)		
	No	13 (10.7)			20 (11.8)		
Henan	Yes	132 (83.0)	χ^2 = 28.68	<0.001**	179 (80.6)	χ^2 = 31.78	<0.001**
	No	27 (17.0)			43 (19.4)		
Liaoning	Yes	131 (65.5)			147 (65.0)		
	No	69 (34.5)			79 (35.0)		
Provincial CDC	Yes	202 (81.4)			270 (81.1)		
	No	46 (18.6)	χ^2 = 4.94	0.026*	63 (18.9)	χ^2 = 6.36	0.012*
Prefectural/County CDC	Yes	164 (72.9)			200 (72.5)		
	No	61 (27.1)			76 (27.5)		

* Significant p-value <0.05.
** Significant p-value<0.001.

Moreover, participants held different opinions on climate change impacting on dengue across CDC levels (Table 2). Over 80% of participants from Provincial CDCs indicated climate change would impact vector-borne diseases compared with significantly fewer participants (72.9%) from Prefectural/County CDCs (χ^2 = 4.94, p = 0.026). In particular, 81.1% from Provincial CDCs indicated that climate change would likely have an influence on dengue, compared with fewer (72.5%) from Prefectural/County CDCs (χ^2 = 6.36, p = 0.012).

Dengue control and prevention

Table 3 shows participants' perceptions of dengue control and prevention. The majority (69.0%) from Yunnan were more likely to indicate dengue had re-emerged, compared with 40.6% from Henan and only 23.8% from Liaoning (χ^2 = 56.08, p < 0.001). Public health professionals across different levels of CDCs also held inconsistent opinions on dengue control and prevention. The proportion of participants from Provincial CDCs who believed that dengue had emerged in recent years was 41.8% compared with those (55.6%) from Prefectural/County CDCs (χ^2 = 6.28, p = 0.012). This finding was supported using multiple logistic regression analysis (see Supplementary table S2), showing participants from Yunnan were significantly more likely to indicate that dengue had re-emerged in recent years (OR = 5.502, 95% CI 2.955–10.245, p < 0.001), when compared to those from Liaoning. Moreover, pairwise comparisons indicated participants from Yunnan were also more likely to indicate so in contrast to those from Henan (see Supplementary table S3). Similarly, Prefectural/County CDC staff were more likely to indicate dengue re-emergence (OR = 2.234, 95% CI 1.203–4.150, p = 0.011), than those in Provincial CDCs.

Although 50.4% of participants from Yunnan perceived some dengue outbreaks were occurring in new geographic areas, most participants from Henan (65.3%) and Liaoning (79.0%) did not believe so (χ^2 = 24.10, p < 0.001). Participants from Prefectural/County CDCs were more likely to believe this to be the case, compared with those from Provincial CDCs (χ^2 = 8.04, p = 0.005).

Around 75% or more of the participants in Henan and Liaoning did not perceive dengue outbreaks to be occurring at unusual times of the year, compared with smaller proportion of the participants in Yunnan (χ^2 = 14.25, p = 0.001). Overall, most (>60%) participants did not believe so, especially those (76.0%) from Provincial CDCs (χ^2 = 7.81, p = 0.005). In addition, male staff were more likely to indicate dengue outbreaks were occurring in new geographic areas (OR = 1.758, 95% CI 1.111–2.779, p = 0.016), and at unusual times of the year (OR = 1.853, 95% CI 1.117–3.075, p = 0.017) (Supplementary table S2).

Participants from Yunnan (59.4%) and Henan (52.8%) were more likely to believe current prevention methods and control programs had been effective, compared with less in Liaoning (28.3%) (χ^2 = 26.95, p < 0.001). Furthermore, around two-thirds of participants from Prefectural/County CDCs indicated they thought these strategies had been effective in reducing dengue incidence, while even less Provincial CDC staff believed so (χ^2 = 21.43, p < 0.001).

Additionally, less than half of the participants across all studied provinces, and 54.5% of Prefectural/County CDC staff, indicated that the population in general was well informed about how to reduce the risk of dengue. Fewer participants from Liaoning and Provincial CDCs indicated this to be the case, compared with public health professionals from Yunnan, Henan and Prefectural/County CDCs, respectively.

Risk factors for dengue fever

In this study, an open-ended question 'What do you think are the main risk factors for dengue in your region' was used to explore public health professionals' perceptions of potential main risk factors for dengue. Table 4 summarizes these results in each province. The most frequently reported risk factors for dengue was 'mosquitoes in high-density', 'imported cases' and 'climate change'. Moreover, participants also thought 'poor environmental conditions', 'internal migrant population', and 'lack of health awareness' were main risk factors.

Discussion

To the best of our knowledge, this is the first study to provide a broad picture of perceptions of dengue in the context of climate change amongst public health professionals across different geographical and climatic zones in China. Our study has demonstrated that the majority of public health professionals believed climate change would impact vector-borne diseases and dengue transmission. However, there were inconsistent opinions across different regions, with a greater proportion of participants from Yunnan and Henan in southwest and central China, respectively, believing climate change would have an impact on vector-borne diseases and specifically, dengue transmission. This is in line with the findings of Tong et al. who reported that CDC staff in Guangdong indicated that they believed climate change would influence the transmission of dengue fever [12].

In the present study, participants from Liaoning were significantly less likely to indicate concerns about the effect of climate change on disease transmission. This could be due to the relatively cooler climate conditions in Liaoning that are not conducive to dengue transmission at present. Nevertheless, although northeast China faces a relatively lower risk of dengue transmission, together with climate change, the highly mobile population in China could introduce imported cases to any regions. Where conditions are con-

Table 3
Public health professionals' perceptions of dengue control and prevention.

	Yunnan		Henan		Liaoning		Statistics	Provincial CDC		Prefectural/County CDC		Statistics
	Yes N (%)	No N (%)	Yes N (%)	No N (%)	Yes N (%)	No N (%)		Yes N (%)	No N (%)	Yes N (%)	No N (%)	
Has dengue re-emerged in recent years?	98 (69.0)	44 (31.0)	52 (40.6)	76 (59.4)	29 (23.8)	93 (76.2)	$\chi^2 = 56.08$**	114 (41.8)	159 (58.2)	65 (55.6)	52 (44.4)	$\chi^2 = 6.28$*
Are some dengue outbreaks occurring in new geographic areas?	70 (50.4)	69 (49.6)	43 (34.7)	81 (65.3)	25 (21.0)	94 (79.0)	$\chi^2 = 24.10$**	86 (31.9)	184 (68.1)	52 (47.3)	58 (52.7)	$\chi^2 = 8.04$*
Are some dengue outbreaks occurring at unusual times of the year?	54 (38.9)	85 (61.1)	31 (25.0)	93 (75.0)	22 (18.3)	98 (81.7)	$\chi^2 = 14.25$*	65 (24.0)	206 (76.0)	42 (38.2)	68 (61.8)	$\chi^2 = 7.81$*
Have current prevention methods and control programs been effective in reducing incidence in this area?	82 (59.4)	56 (40.6)	66 (52.8)	59 (47.2)	34 (28.3)	86 (71.7)	$\chi^2 = 26.95$**	109 (40.2)	162 (59.8)	73 (66.4)	37 (33.6)	$\chi^2 = 21.43$**
Is the population in general well informed about how to reduce the risk of dengue?	67 (48.2)	72 (51.8)	54 (42.9)	72 (57.1)	30 (25.0)	90 (75.0)	$\chi^2 = 15.58$**	90 (33.2)	181 (66.8)	61 (54.5)	51 (45.5)	$\chi^2 = 14.99$**

* Significant p-value <0.05.
** Significant p-value <0.001.

Table 4
Potential main risk factors for dengue fever in the three provinces.

Potential main risk factors	Yunnan N (%)	Henan N (%)	Liaoning N (%)
Mosquitoes in high-density	23 (32.9)	16 (19.0)	13 (44.8)
Imported cases	10 (14.3)	30 (35.7)	10 (34.5)
Climate change	15 (21.4)	8 (9.5)	3 (10.3)
Poor environmental conditions	7 (10.0)	10 (11.9)	2 (6.9)
Internal migrant population	5 (7.1)	11 (13.1)	1 (3.4)
Lack of health awareness	6 (8.6)	7 (8.3)	0
Others	4 (5.7)	2 (2.4)	0

Keywords of risks were listed in the table. The frequency did not equal to total 630 as some participants either did not answer the question or answered unclear/unsure about the potential main risk factors.

ducive to the breeding of the dengue vectors, local transmission can then occur. Therefore, preventive measures, control strategies and the necessary knowledge to respond to potential dengue emergence and outbreaks are imperative in the context of a warming climate which may see dengue cases appearing in new areas, especially during the summer period in the province [27]. It is important for local health authorities, CDC senior executives, and professional organizations to exercise preparedness for potential outbreaks.

Moreover, compared with participants from provincial CDCs, Prefectural/County level CDC professionals were significantly less likely to believe climate change would affect vector-borne diseases and dengue. Conversely, they were more likely to indicate dengue had emerged/re-emerged in recent years, or had occurred in new geographic areas or at unusual times of the year. This may imply that an association between more dengue outbreaks and climate change is not being made. Previous studies have suggested CDC staff may benefit from more training on the adverse health effects of climate change on the transmission of diseases [12,22,23], but it is unclear if the level of training obtained is the underlying reason for the discrepancy in the opinion of the staff at different levels of CDCs.

Of the three study provinces, Yunnan has the highest incidence of dengue [28]. It is therefore not surprising that participants in this province were more likely than other participants to indicate dengue had emerged or re-emerged. This is plausible because most dengue cases are reported in southwest and south China and indeed Yunnan and Guangdong Provinces have previously faced serious dengue emergence/re-emergence, with reported expansion of the disease into new areas [29,30]. In addition, male public health professionals were more likely to indicate dengue outbreaks in new geographic areas and at unusual times of the year. The reason could be that male staff were more likely to conduct field surveillance and epidemiological investigation with more frontline experience on dengue emergence/re-emergence.

In this study, less than 30% of participants from Liaoning were likely to believe current prevention strategies were effective, which may imply that these have not been effective, and that region-specific/customised control measures may be necessary. With the increasing number of imported and local dengue cases and the broadening of affected areas, current dengue control and prevention measures may need to be revised. Importantly, more than half of participants believed the population was not well informed about how to reduce the risk of dengue. As reported elsewhere [31,32], more health promotion activities among communities would help to raise public health awareness about reducing dengue risks. Community residents could be guided to empty and clean domestic water containers, used tyres, discarded packaging, and blocked gutters and other containers, to reduce the risk of dengue mosquitoes breeding around their homes [33].

A number of major risk factors for dengue fever were identified in open-ended questions. These are consistent with the findings of other studies [12,34,35], including that high-density mosquito populations increase the contact opportunities with humans and significantly contribute to the transmission of dengue infection [3,36]. A large number of imported cases from overseas, especially Southeast Asia, may initiate dengue outbreaks locally in China [37]. In the long term, warmer and wetter weather due to climate change may provide ideal environmental conditions for dengue vectors, and increase mosquito populations in new areas [38]. Moreover, the internal migrant population movement and international travel can also facilitate dengue transmission, and the lack of health awareness amongst these groups can increase the difficulty of control and prevention of the disease. Participants in Yunnan where the tropical/sub-tropical climate is conducive to the breeding of the vectors, indicated mosquitoes in high-density were the most significant factor increasing the risk of dengue, followed by climate change and imported cases. Participants from Henan (temperate climate) placed the highest importance on the imported cases, and also indicated the internal migrant population who may aid in the transmission of the disease if they are viraemic and move to an area where the population has low immunity to the disease [17]. Participants from Liaoning, where dengue is not a significant public health problem, also recognised high abundance of dengue vectors as a major risk factor. Notably, climate change was ranked lower than other risk factors in both Henan and Liaoning. However, warming temperatures could contribute to mosquitoes' survival through the winter [39,40], and also reduce the extrinsic incubation period of the virus. Overall, strengthening mosquito control measures is necessary to reduce the incidence of dengue fever in China, as is raising health awareness amongst the public about environmental factors associated with dengue fever transmission and its prevention. Such health intervention is achievable, for example, two studies in Shantou and Yichang had found health education campaign significantly improved the knowledge and practice of residents to protect from dengue risks [31,32]. Further promotion of the health education campaigns in wider areas for community members would facilitate dengue control.

The limitations of this study should be acknowledged. Firstly, only 11 CDCs participated in this study. As such, the results may not be representative of all public health professionals in China. Secondly, although the questionnaire was designed in English and then translated into Chinese, there may be some minor anomalies in the translation and interpretation of data. Thirdly, participants may tend to overestimate or underestimate their knowledge, which may lead to potential response bias. However, the experienced staff with work experience of at least ten years generally had lower educational level, while staff with a higher educational level had less working experience (up to ten years) (see Table S4). Hence, the potential for response bias is minimized. Nevertheless, it is believed that the study sites selected adequately reflect the varied dengue risk levels across different climatic and geographical zones in China [5,7], and a corresponding range of responses from these public health professionals provides insights into dengue control and prevention in the context of climate change in China. The results provide an evidence base from which to inform policy-makers, service providers and other relevant stakeholders for dengue control and prevention in China.

Conclusions

This study found the majority of surveyed public health professionals believed that climate change would impact vector-borne disease and dengue in China. Participants from southwest China and Prefectural/County-level CDCs, were more likely to indicate the emergence and re-emergence of dengue. The major risk factors for the disease were perceived to be mosquitoes in high-density, imported cases and climate change. Providing more information for staff in the lower levels of CDCs may help in containing a possible increase in this climate-sensitive disease as a result of climate change. Moreover, a focus on developing better control strategies including more dengue-specific health education among community members would also help to reduce the risk of dengue in China, particularly in light of environmental changes heightening risks associated with the transmission of vector-borne diseases.

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Competing interests

None declared.

Ethical approval

Not required.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jiph.2018.12.010.

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