One Health 15 (2022) 100452

Contents lists available at ScienceDirect

One Health

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

The association between dengue case and climate: A systematic review and meta-analysis

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ARTICLE INFO

Keywords:
Dengue cases
Climate
Systematic review
meta-analysis

ABSTRACT

Although previous research frequently indicates that climate factors impact dengue transmission, the results are inconsistent. Therefore, this systematic review and meta-analysis highlights and address the complex global health problems towards the human-environment interface and the inter-relationship between these variables. For this purpose, four online electronic databases were searched to conduct a systematic assessment of published studies reporting the association between dengue cases and climate between 2010 and 2022. The meta-analysis was conducted using random effects to assess correlation, publication bias and heterogeneity. The final assessment included eight studies for both systematic review and meta-analysis. A total of four meta-analyses were conducted to evaluate the correlation of dengue cases with climate variables, namely precipitation, temperature, minimum temperature and relative humidity. The highest correlation is observed for precipitation between 83 mm and 15 mm ($r = 0.38$, 95% CI = 0.31, 0.45), relative humidity between 60.5% and 88.7% ($r = 0.30$, 95% CI = 0.23, 0.37), minimum temperature between 6.5 °C and 21.4 °C ($r = 0.28$, 95% CI = 0.05, 0.48) and mean temperature between 21.0 °C and 29.8 °C ($r = 0.07$, 95% CI = −0.1, 0.24). Thus, the influence of climate variables on the magnitude of dengue cases in terms of their distribution, frequency, and prevailing variables was established and conceptualised. The results of this meta-analysis enable multidisciplinary collaboration to improve dengue surveillance, epidemiology, and prevention programmes.

1. Introduction

Dengue fever is now the most significant vector-borne viral disease in terms of global morbidity and mortality [1–3]. It is estimated that about 50% of the global population in 128 countries is at risk of dengue fever [4]. It is transmitted through the bite of an infected *Aedes* mosquito and is now spreading more widely due to climate change [1,3,5,6]. The World Health Organization (WHO) released its global strategy for dengue prevention and control, stating its objective to reduce global dengue-attributable mortality and morbidity by 50% and 25% by 2020 [7]. This reduction can be achieved partly by implementing improved outbreak prediction and detection through coordinated epidemiological and entomological surveillance [8]. However, holistic and trans-disciplinary approaches are necessary to address the global health issues which are influenced by various complex factors [9]. For instance, the One Health approach introduced by WHO is characterised as an integrated, unified method aimed at balancing and optimising the health of people, animals, and ecosystems over time [10]. In dengue control, this approached can be demonstrated through the interaction of systems surrounding human, vector, and environment as this disease has multiple underlying causes, including virological factors, vector-borne disease, environmental factors, and human factors [11]. Hence, the dengue control in Malaysia is comprised of three major components: vector control and surveillance, community participation and enforcement, and the search and destruction of *Aedes* breeding [12]. The implementation of these controls required the collaboration and coordination of numerous sectors and disciplines, including public health, law enforcement, and the community.

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https://doi.org/10.1016/j.onehlt.2022.100452
Received 11 August 2022; Received in revised form 29 October 2022; Accepted 30 October 2022

A One Health strategy is characterised as an integrated, unified method aimed at balancing and optimising the health of people, animals, and ecosystems over time [10]. The interaction of systems surrounding humans, vectors, and the environment exemplifies the One Health concept in dengue control. This disease is caused by a variety of reasons, including virological factors, vector-borne disease, environmental factors, and human factors [11]. Dengue control in Malaysia is comprised of three major components: vector control and surveillance, community participation and enforcement, and the search and destruction of Aedes breeding sites [12]. Implementing these controls necessitated the collaboration and coordination of numerous sectors and disciplines, including public health, law enforcement, and the community.

Studies have demonstrated that climatic parameters influence seasonal variation and the global distribution of dengue [9,13]. Temperature, rainfall, humidity, and their inter-relations are all proven to significantly affect mosquito population dynamics and disease transmission cycles. Forecasting models based on routinely aggregated weekly dengue reports, mean temperature, and meteorological data, such as cumulative rainfall predicted dengue incidence up to 16 weeks in advance at the national level [10,14]. Research has shown that temperature readings from commonly used macroclimate datasets are often dissociated from the thermal tolerances of species that inhabit different ecosystems with unique microclimates. Additional factors, such as thermal microclimates influenced by vegetation cover, topography, and types of environmental mosquito larval habitat sites may impact mosquito population and distribution by allowing mosquitoes to survive where the overall macroclimate conditions seem inappropriate. In addition, a locality's population, building density, and socioeconomic factors can impact mosquito-human contact and virus transmission. Thus, it is critical to consider several domains to monitor *Aedes* abundance and distribution to better forecast dengue outbreaks in *Aedes*-infested areas. Due to dengue's climate-sensitive nature, it is essential to address this issue and the impact of climatic factors on occurrence and prevalence. This review and meta-analysis attempted to identify the correlation between dengue cases and climatic factors, considering that dengue is a significant health problem. The result of this meta-analysis can be used to improve the public health sector in terms of dengue surveillance, risk assessments and outbreak preparedness.

2. Material and methods

The systematic review and meta-analyses were performed on climate, dengue cases, and mosquito population dynamics by implementing PRISMA guidelines [15]. The articles indexed in this review correspond to MDPI, PubMed, Science Direct and Google Scholar databases. The search was limited to articles published between January 2010 to April 2022. Search terms were based on a PICO question format. The search terms included 'environment', 'climate', 'meteorological', 'temperature', 'humidity', 'rainfall', 'wind speed', 'correlation', 'association', '*Aedes*', 'dengue case' and 'abundance'. The terms were selected based on search strings created from exposure, subject and outcome of the desired study. Boolean operators 'OR', 'AND', and 'NOT' were used to narrow or broaden database results.

The initial selection by title and abstract was conducted independently based on the inclusion/exclusion criteria. Articles that presented one or more terms with dengue cases and climate were included in the title selection. Subsequently, the articles were assessed comprehensively to validate the presence of relevant data usable for the systematic review and meta-analysis. The disagreements about article inclusion were resolved through discussion between the first and second authors. The included articles were tabulated to highlight the following information: author and year of publication, study location, climate zone, data period, dengue data source, meteorological data source, statistical method and measure of effect.

The Inclusion criteria were (i) articles measuring the association between climate variables and dengue cases specifically attributable to *Ae. Aegypti* and *Ae. Albopictus*; (ii) the articles comprised field studies; (iii) associations concerning any stage of the mosquito life cycle; (iv) precise and clear association measurement; (v) provides r and 95% CI or complete data for calculating r with 95% CI. Meanwhile, the exclusion criteria were; (i) case studies and literature reviews that included previously published data; (ii) notification of outbreaks; clinical descriptions of diseases, pathogenicity and diagnosis in humans or animals; purely descriptive studies; experimental laboratory studies; (iii) case studies and literature reviews that included previously published data; (iv) duplicate articles or inaccessible reviews attributable to language or lack of full-text access. The quality of the selected articles was assessed using an 11-item checklist from the Agency for Healthcare Researched and Quality (AHRQ). An item is scored '0' if the answer is 'NO' or 'UNCLEAR', and the item is scored '1' if the answer is 'YES' or 'NOT APPLICABLE'. The article quality is assessed based on score: '0–3' = low quality; '4–7' = moderate quality; '8–11' = high quality.

Correlation coefficient and SE were used to assess the association between dengue cases and climate. Correlations with a *p*-value <0.05 were considered statistically significant and included in the meta-analysis. The heterogeneity between studies was assessed using the I^2 statistic to describe the variation percentage across studies due to heterogeneity rather than chance [12,16]. A random-effects model accounted for both within- and between-study heterogeneity. The forest plots were produced to visually assess each study's r and 95% CI. The potential publication bias was assessed using the Begg and Mazumdar rank association and Egger's regression tests to quantify the bias captured by the funnel plot [17,18/13,14]. The analysis was performed using Comprehensive Meta-Analysis (version 3; Biostat Inc.) software, and the statistical significance was a two-tailed $p < 0.05$. Fig. 1 summarises article selection according to PRISMA guidelines.

3. Results and discussion

The initial search from the four databases yielded 1672 records; 430 publications remained after the title and abstract screening. Another 422

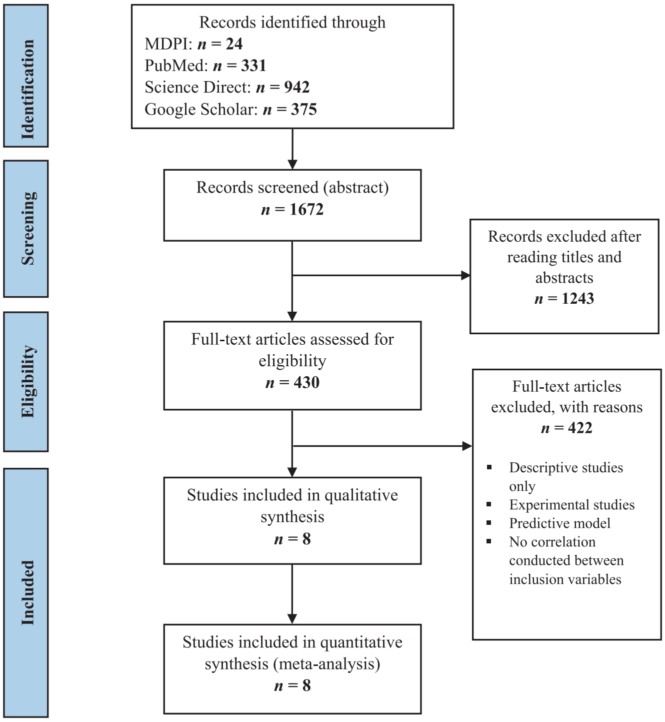

Fig. 1. PRISMA guideline-based article selection flowchart.

publications were eliminated because they were descriptive, experimental, and predictive models, with no association between the included variables. Finally, eight publications remained after strict inclusion criteria screening (Table 1). All studies were conducted monthly, and the results showed that precipitation was substantially associated with dengue incidence. Seven studies indicated that temperature is the second most significant climate variable [19–25], followed by relative humidity with four studies [19,21,22,26] and minimum temperature with three studies [23,24,26]. Another study listed significant variables like maximum temperature [26], atmospheric pressure, sky clearness and wind speed [20]. Most studies were conducted in tropical climates found in Mérida City, México [25], the Philippines [20,22], and Sri Lanka [19]. Two studies considered Nakhon Si Thammarat [26] and Bangkok, Thailand [21], indicative of the tropical monsoon climate. The last two studies were conducted in Guangzhou, China [23,25], which has a subtropical climate.

The articles indicated average precipitation between 83 mm [25] and 150 mm [21]. The r and 95% CI were extracted, and a forest plot was used to show the association between precipitation and dengue incidences. Monthly precipitation correlates positively to dengue incidences in all studies. A moderate positive correlation is found between the lagging two-months precipitation and dengue incidences in Eisen et al. [25] (r = 0.55, 95% CI = 0.17,0.79); lagging four-months and three-months precipitation in Sang et al. [23] (r = 0.54, 95% CI = 0.38, 0.66) (r = 0.53, 95% CI = 0.37, 0.66).

There is a weak correlation between the same month precipitation (no lag) and dengue incidences in Yu et al. [22] (r = 0.38, 95% CI = 0.09, 0.61) and Faruk et al. [19] (r = 0.41, 95% CI = 0.31, 0.50); lagging one-month precipitation in Eisen et al. [25] (r = 0.48, 95% CI = 0.08, 0.74) and Polwiang et al. [21] (r = 0.37, 95% CI = 0.24, 0.49); lagging two-months precipitation in Sang et al. [23] (r = 0.45, 95% CI = 0.28, 0.59) and Polwiang et al. [21] (r = 0.40, 95% CI = 0.26, 0.49), and lagging five-months precipitation in Sang *et al* [23] (r = 0.38, 95% CI = 0.20, 0.54). A very weak correlation is found between lagging one-month precipitation and dengue incidences in Sang et al. [23] (r = 0.22, 95% CI = 0.03, 0.40); lagging two-months precipitation in Wongkoon et al. [26] (r = 0.20, 95% CI = 0.10, 0.30); and lagging three-months precipitation in Polwiang et al. [21] (r = 0.25, 95% CI = 0.10,

Table 1
Included articles' study profile to determine the association between climate, dengue cases and mosquito population.

Author (year)	Location (Climate)	Study Period	Data source	Climate data source	Study variables	Statistical method (Measure of effect)	Main Findings
Faruk et al., [19/15]	Sri Lanka (Tropical)	2015–2019	Health Ministry of Sri Lanka	NASA Power Data Access Viewer	Atmospheric pressure Precipitation Relative humidity Sky clearness Temperature Wind speed	Spearman's correlation (r_s)	There is a significant negative correlation between dengue incidence, monthly atmospheric pressure from 2015 to 2018, and monthly temperature from 2015 to 2019. Dengue incidence positively correlates with monthly relative humidity throughout the study period.
Francisco et al., [20/16]	Manila, Philippines (Tropical)	2012–2014	Department of Health	Tropical Rainfall Measurement Mission Terra Moderate Resolution Image Spectroradiometer	Ovitrap Index (OI) Precipitation Temperature	Pearson's correlation I	Monthly dengue incidence positively correlates with the prior months' precipitation, and three months prior temperature and OI.
Polwiang, [21/17]	Bangkok, Thailand (Tropical Monsoon)	2003–2016	Bureau of Epidemiology	Department of Meteorology, Ministry of the Digital Economy and Society	Precipitation Relative humidity Temperature	Spearman's correlation (r_s)	Rainfall and humidity positively correlate with dengue cases.
Yu et al., [22/18]	Philippines (Tropical)	2015–2019	Department of Health	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)	Precipitation Relative humidity Temperature	Pearson's correlation I	Dengue case has a weak positive correlation with precipitation and relative humidity, but a weak negative correlation with temperature
Sang et al., [23/19]	Guangzhou, China (Subtropical)	2003–2014	Notifiable Infectious Disease Report System	China Meteorological Data Sharing Service System	Minimum temperature Precipitation	Spearman's correlation (r_s)	The previous four months' minimum temperature and precipitation positively correlated with dengue cases/
Shen et al., [24/20]	Guangzhou, China (Subtropical)	2006–2014	China Centre for Disease Control and Prevention	China Meteorological Data Sharing Service System	Breteau index (BI) Minimum temperature Temperature	Spearman's correlation (r_s)	The current month's BI, average temperature and previous month's minimum temperature were positively associated with dengue cases
Eisen *et al*, [25/21]	Mérida City, México (Tropical)	2009–2010	Servicios de Salud de Yucatán	Comision Nacional del Agua	Precipitation Temperature	Spearman's correlation (r_s)	There was a significant weak positive correlation between dengue cases, rainfall and relative humidity, including a weak negative correlation between dengue cases and temperature
Wongkoon et al., [26/22]	Nakhon Si Thammarat, Thailand (Tropical Monsoon)	1981–2012	Bureau of Epidemiology, Department of Disease Control	Department of Meteorology	Maximum temperature Minimum temperature Precipitation Relative humidity	Spearman's correlation (r_s)	Monthly DF incidences were significantly associated with monthly minimum temperature, relative humidity, rainfall

0.38). The I^2 heterogeneity test for monthly precipitation and dengue incidences meta-analysis is 58.75%, suggesting that 58.75% of the variability in the correlation of precipitation is due to heterogeneity and only 41.25% is due to chance.

Since the heterogeneity is relatively low, further meta-regression analysis was not conducted. Begg's and Egger's tests gave two-tailed p-values of 0.27 and 0.09 ($p > 0.05$), respectively, indicating no publication bias. Meanwhile, the pooled correlation coefficient from selected articles indicates a positive association between monthly precipitation and the number of dengue incidences. The r value is 0.38 and the 95% confidence interval values are 0.31 and 0.45 (Fig. 2A).

The mean relative humidity (RH) is 72.9% in Bangkok, Thailand [21], 60.5 to 88.7% in Philippines [22] and 80.6% in Sri Lanka [19]. All articles indicate a positive correlation between monthly RH and dengue incidence. Faruk et al. [19] indicated a weak positive association between the variables for the same month in 2016 and 2019. The r values were 0.38 (95% CI = 0.38, 0.28) and 0.48 (95% CI = 0.39, 0.56) respectively. Polwiang et al. [21] also indicated a weak positive correlation in lagging one- and two-months data; the r values were 0.38 (95% CI = 0.24, 0.50) and 0.39 (95% CI = 0.26, 0.51) respectively. Yu et al. [22] indicated a very weak correlation between the same month's RH and dengue incidence ($r = 0.15$, 95% CI = 0.05, 0.25). There were similar observations by Faruk et al. [19] in year 2015 ($r = 0.21$, 95% CI = 0.10, 0.31), 2017 ($r = 0.25$, 95% CI = 0.14, 0.35) and 2018 ($r = 0.24$, 95% CI = 0.13, 0.34); two-months lag RH in Wongkoon et al. [26] ($r = 0.15$, 95% CI = 0.05, 0.25); and three-months lag RH in Polwiang et al. [21] ($r = 0.26$, 95% CI = 0.13, 0.4).

The I^2 heterogeneity test statistic equals 74.34%, suggesting that the variability in the precipitation estimates is due to heterogeneity and only 25.66% is due to chance. Begg's and Egger's tests gave two-tailed p-values of 0.42 and 0.75 ($p > 0.05$), respectively, indicating no publication bias. The pooled correlation coefficient indicates a positive association between monthly relative humidity and the number of dengue incidences ($r = 0.30$, 95% = 0.23, 0.37) (Fig. 2B).

The minimum temperature in Guangzhou, China, ranged from 6.5 to 12.1 °C between January and February [24]. A minimum temperature of 21.4 °C was observed in Nakhon Si Thammarat, Thailand [26]. The monthly minimum temperature also displays positive and negative correlations to dengue incidences. A moderate positive correlation between minimum temperature and dengue cases are observed in Sang et al. [23] study at a month lag ($r = 0.49$, 95% CI = 0.33, 0.63), two-months lag ($r = 0.59$, 95% CI = 0.45, 0.70) and three-months lag ($r = 0.52$, 95% CI = 0.36, 0.70). Studies by Wongkoon et al. [26] for the same month and Sang et al. [23] at a four-month lag indicates a weak positive correlation between minimum temperature and dengue incidences with the r values of 0.31(95% CI = 0.21, 0.39) and 0.30 (95% CI = 0.12, 0.47) respectively. Conversely, Shen et al. [24] indicate a weak negative association between climate variables and dengue incidences on minimum temperature for the same month ($r = -0.20$, 95% CI = −0.37, −0.01) and for one month lag ($r = -0.18$, 95% CI = −0.36, 0.01).

The I^2 test showed that 92.29% of the variability concerning

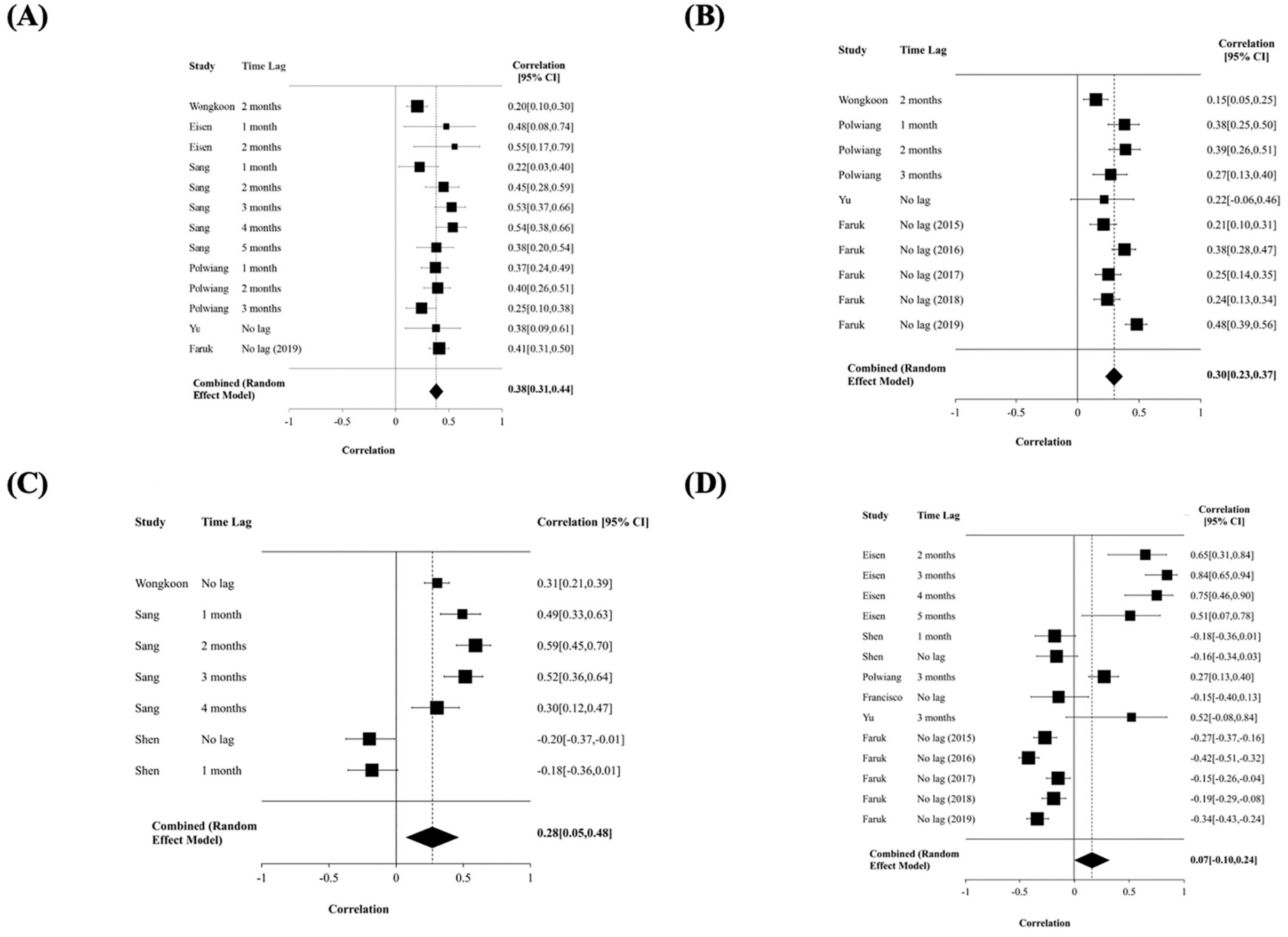

Fig. 2. Meta-analysis of climate variables and dengue incidence. Figure: (A) = precipitation; (B) relative humidity; (C) minimum temperature; (D) mean temperature. Note: The box size in the graph reflects each study's relative weight.

minimum temperature effects estimates is due to heterogeneity, and only 7.71% is due to chance. Subsequent analysis using Begg's and Egger's tests also showed no publication bias; the two-tailed test p-values were 0.23 and 0.95, respectively. The random effect model's pooled association of monthly minimum temperature and dengue incidences indicate a positive association with an r value of 0.28 (95% CI = 0.05, 0.48) (Fig. 2C).

The average temperature of selected articles ranges from 21.0 °C to 25.0 °C in Mexico [25], 21.9 °C in China [24] and 29.8 °C in Thailand [21]. Monthly temperature exhibits positive and negative correlations with dengue incidences. The strongest positive association between monthly temperature and dengue incidences are shown by Eisen et al. [25] at two-months lag (r = 0.65, 95% CI = 0.31, 084), three-months lag (r = 0.84, 95% CI = 0.65, 0.94), four-months lag (r = 0.75, 95% CI = 0.46, 0.90) and five-months lag (r = 0.51, 95% CI = 0.07, 0.78). Meanwhile, Yu et al. [22] found a moderate positive correlation between monthly temperature and dengue incidences at three-months lag (r = 0.52, 95% CI = −0.08, 0.84). Weak positive correlations between monthly temperature and dengue incidences at three-months lag are indicated by Polwiang et al. [21] (r = 0.27, 95% CI = 0.13, 0.40) and for the same month in year 2015 by Faruk et al. [19] (r = 0.52, 95% CI = −0.34, 0.03).

In contrast, Shen et al. [24/20] found a negative correlation between monthly temperature and dengue incidences for the same month (r = −0.16, 95% CI = −0.34, 0.03) and one-month lag (r = −0.18, 95% CI = 0.36, 0.01). Meanwhile, Faruk et al. [19] found a weak negative correlation between monthly temperature and dengue incidence in 2016 and 2019 with r = −0.42 (95% CI = −0.51, −0.34), including a very weak negative correlation between monthly temperature and dengue incidences in 2015 (r = −0.27, 95% CI = −0.37, −0.16), 2017 (r = −0.15, 95% CI = −0.26, −0.04) and 2018 (r = −0.19, 95% CI = −0.29, 0.08).

The I^2 heterogeneity test indicates 58.75%, suggesting that the variability in the association of precipitation effects estimates is due to heterogeneity, and only 41.25% is due to chance. Begg's and Egger's tests also gave two-tailed p-values of 0.27 and 0.09 ($p > 0.05$), respectively, indicating no publication bias. The pooled correlation coefficient indicates a positive association between mean monthly temperature and the number of dengue incidences (r = 0.07, 95% CI = −0.1, 0.24) (Fig. 2D).

The meta-analysis above indicates that climate variables (temperature, minimum temperature, precipitation and relative humidity) positively correlate to dengue cases. The highest correlation is for precipitation (r = 0.38, 95% = 0.31, 0.45), followed by relative humidity (r = 0.30, 95% CI = 0.23, 0.37), minimum temperature C (r = 0.28, 95% CI = 0.05, 0.48), and mean temperature range (r = 0.07, 95% CI = −0.1, 0.24). Precipitation is crucial for the mosquito lifecycle as it spends its juvenile phases, egg to pupae, in water. The result indicates that dengue cases have a significant positive association with the monthly precipitation at one to five months lag [21,23,25]. Lagged precipitation has a crucial effect on mosquito development, external dengue incubation period, and virus incubation period in the host [27].

Precipitation affected the abundance of adults, larvae and eggs of *Ae. albopictus* [28,29], and the abundance of eggs and adults of *Ae. aegypti* [30,31]. It is attributable to eggs hatching inside containers after flooding and vegetation growth after rains [32]. Precipitation also has a more significant effect on the abundance of *Ae. aegypti* than *Ae. albopictus* due to the species' preference for ovipositing in artificial containers, which are prone to have more apparent influence from the precipitation than the vegetation [31].

Meanwhile, *Ae. albopictus* larval productivity is significantly affected by the preceding month's rainfall [33]. The accumulated precipitation generates outdoor oviposition sites for *Ae. aegypti*, but extreme precipitation events can flush out some larval sites [34]. Time lag concerning rainfall in the previous week provides sufficient humidity and moisture for mosquito activity in the current week and possibly serves to trigger egg hatching [35]. In contrast, a study reported that precipitation during the preceding week negatively affects *Ae. albopictus* egg abundance [29]. The observed negative relationship between egg abundance and rainfall could result from the temporal coincidence between decreasing temperatures and autumn rainfall that inhibits egg hatching [29].

Extreme weather conditions, such as floods and droughts, benefit mosquito survival in some conditions. In an arid environment, as in Kenya, the *Ae. aegypti* egg and adult were positively associated with floods because mosquito habitats may dry after regular precipitation [36]. The water necessary for developing immature mosquito stages may dry up during drought, and the water volume is insufficient to oviposit or trigger egg hatching. In brief, heavy rainfall can flush away immature life stages of the *Aedes* mosquito in the short term. However, precipitation creates conditions conducive for mosquito breeding and survival in the long term; hence, most dengue incidences and mosquito density were correlated with precipitation from prior months.

Humidity refers to the ratio of water vapour to the saturating water vapour at the same temperature [37,38]. The relative humidity is negatively correlated with air temperature [38]. Hence, the relative humidity is low in high temperatures and *vice versa*. The mosquito respiratory system consists of the trachea (air pipe) and spiracle (holes in the body wall of mosquitoes). This spiracle does not have a regulatory mechanism and is always wide open. The fluids in the body evaporate when the humidity is low [39], causing mosquito death. The lowest limit of humidity for *Ae. aegypti* to survive is 60% [40], and the relative humidity indicated by all studies is above the range, which may be the reason for the positive correlation with dengue cases.

However, the mean temperature of selected studies ranges from 21.0 °C to 29.8 °*C. prior* studies had shown that the weekly *Ae. aegypti* female presence, detected by mosquito collection using aspirator from households, significantly correlated with weekly mean ranging from 26 °C to 28 °C [35]. The optimal temperature for dengue transmission is 29.3 °C [41]. Eisen et al. [25] showed that the indoor presence of female *Ae. aegypti* started to increase from May to June. Presence peaked from July to September when the mean monthly daily temperatures in Mérida City ranged from 21 °C to 25 °C from November to March and exceeded 27 °C from April to October. The temperature is within the mean temperature range, positively correlated with biting, development, fecundity, and mortality [42]. It could also be attributed to the fact that *Ae. aegypti* is driven indoors to reduce mortality when the outdoor temperature is higher than 21 °C [43]. However, Polwiang et al. [21] show that the increasing temperature contributes to a minor negative association because the mean temperature in Bangkok was relatively constant throughout the year. High temperatures may reduce vector populations in warmer regions where temperatures are close to the mosquito survival limit [44].

The minimum temperature of selected studies ranges from 6.5 °C to 21.4 °C. *Ae. aegypti* has a higher low-temperature tolerance compared to *Ae. albopictus*. It leads to lower mortality of adult *Ae. aegypti* at low temperatures. Moreover, the temperature has a milder effect on *Ae. aegypti* presence [43].

Nonetheless, different local adaptations by *Aedes* species to climatic changes were reported both in and out of Florida [45,46]. The study by Bonizzoni et al. [47] observed that *Ae. albopictus* prefer to live in cooler areas in Florida. Shen et al. [24] identified the threshold in the relationship between the current month's minimum temperature and dengue cases as 18.25 °C. Since the extrinsic incubation period decreased when the temperature increased from 18 °C to 31 °C. *Ae. albopictus* may not transmit dengue at temperatures below 18 °C [48].

4. Conclusions

This systematic review and meta-analysis of the association between dengue cases and climate variables highlights dengue transmission's most vital variables. According to the result, the precipitation, relative humidity, minimum temperature and mean temperature are climate variables associated with dengue cases. Precipitation plays a vital role in mosquito survival at juvenile stages, while relative humidity prevents mosquito habitats and adult mosquito from drying up. The spiracle on the adult mosquito body is always wide open due to absent of a regulatory mechanism, hence in low humidity, the fluids in the body can evaporate and causing mosquito death. The survival of mosquito and extrinsic incubation period of dengue virus has the optimum temperature range of 18 °C to 31 °C. The temperature below or above the range may decrease mosquito survival and dengue transmission rates. On the other hand, the mean temperature has a minor effect on dengue transmission in tropical countries because they have relatively constant temperatures. This information could be used in developing the One Health approach, which involved the collaboration and communication of interdisciplinary between meteorological and health department for better surveillance, epidemiological and prevention activities to halt dengue transmission. However, further studies should investigate environmental and entomological parameters to determine dengue association with the specified parameters.

Authors' contribution

Nur Athen Mohd Hardy Abdullah, Nazri Che Dom, Siti Aekbal Salleh, Hasber Salim and Nopadol Precha designed the study; Nur Athen Mohd Hardy Abdullah and Nazri Che Dom performed initial and finalised study selection for systematic review, compiled data and performed statistical analysis, drafted and review the manuscript and Siti Aekbal and Hasber Salim interpreted the data and wrote the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

This study has received funding from the Fundamental Research Grant Scheme, Ministry of Higher Education Malaysia (600-RMC/FRGS 5/3 (141/2021).

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