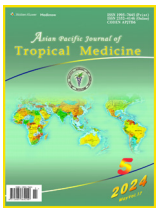

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Global systematic review and meta−analysis of knowledge, attitudes, and practices towards dengue fever among the general population

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ABSTRACT

Objective: To determine the global level of knowledge, attitudes, and practices towards dengue fever among the general population.

Methods: To complete this systematic review and meta-analysis, a thorough search for pertinent English-language literature was undertaken during the study's extension until October 2023. The search used Google Scholar, Scopus, PubMed/MEDLINE, Science Direct, Web of Science, EMBASE, Springer, and ProQuest. A quality assessment checklist developed using a modified Newcastle-Ottawa Scale for the cross-sectional study was used to evaluate the risk of bias in the included papers. Inverse variance and Cochran *Q* statistics were employed in the STATA software version 14 to assess study heterogeneity. When there was heterogeneity, the Dersimonian and Liard random-effects models were used.

Results: 59 Studies totaling 87353 participants were included in this meta-analysis. These investigations included 86278 participants in 55 studies on knowledge, 20196 in 33 studies on attitudes, and 74881 in 29 studies on practices. The pooled estimates for sufficient knowledge, positive attitudes, and dengue fever preventive behaviors among the general population were determined as 40.1% (95% *CI* 33.8%-46.5%), 46.8% (95% *CI* 35.8%-58.9%), and 38.3% (95% *CI* 28.4%-48.2%), respectively. Europe exhibits the highest knowledge level at 63.5%, and Africa shows the lowest at 20.3%. Positive attitudes are most prevalent in the Eastern Mediterranean (54.1%) and Southeast Asia (53.6%), contrasting sharply with the Americas, where attitudes are notably lower at 9.05%. Regarding preventive behaviors, the Americas demonstrate a prevalence of 12.1%, Southeast Asia at 28.1%, Western Pacific at 49.6%, Eastern Mediterranean at 44.8%, and Africa at 47.4%.

Conclusions: Regional disparities about the knowledge, attitude and preventive bahaviors are evident with Europe exhibiting the highest knowledge level while Africa has the lowest. These findings emphasize the importance of targeted public health interventions tailored to regional contexts, highlighting the need for region-specific strategies to enhance dengue-related knowledge and encourage positive attitudes and preventive behaviors.

KEYWOEDS: Break-bone fever; Knowledge; Attitudes; Practices

Significance

This systematic review and meta-analysis aims to study the global landscape of knowledge, attitudes, and practices regarding dengue fever among the general population. The results showed significant disparities in knowledge levels exist across regions, with Europe exhibiting the highest levels of knowledge and Africa exhibiting the lowest. These results underscore the critical need for targeted public health interventions tailored to regional contexts. Identifying the importance of region-specific strategies in this study highlights possibilities for improving dengue knowledge, fostering positive attitudes, and promoting preventive behaviors throughout the world, thus contributing to a better control and management of the disease.

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1. Introduction

Dengue fever, transmitted primarily by *Aedes* (*Ae.*) *aegypti* and *Ae. albopictus* mosquitoes, is one of the globally impactful mosquito-borne diseases heightened by human-induced global climate changes[1,2]. Annually, this virus triggers around 390 million illness cases, posing a threat to 3.9 billion people across 128 countries[3]. The disease becomes endemic in tropical and subtropical regions during the rainy season when *Aedes* mosquitoes proliferate[4].

Despite governmental health programs aiming to control dengue, its incidence persists in rising. This increase is strongly associated with dengue fever's epidemiology and ecology, intertwined with human behaviors responding to climate change[4]. Dengue fever, characterized by sudden onset and high incidence, often leads to widespread outbreaks, resulting in severe public health emergencies[5].

Contributing factors to dengue spread encompass uncontrolled urbanization, population growth, and insufficient preventive measures in endemic areas[6]. Severe dengue cases may lead to life-threatening complications such as bleeding or severe shock, and currently, there is no specific antiviral treatment available[3].

The introduction of the Dengvaxia vaccine in 2015 manufactured by Sanofi-Pasteur, although exhibiting only 60% effectiveness and a low protective level against the DENV-2 virus, signifies a step towards controlling the disease. However, its availability in low-income countries might take several years[7,8]. Consequently, the most effective approach to prevent dengue spread remains the control of dengue virus vectors[3].

Prevention and control strategies involve adopting preventive behaviors like using mosquito nets, repellent sprays, and mosquito coils, eliminating stagnant water, and practicing effective waste management to curb mosquito vector breeding[9]. Knowledge, attitudes, and behaviors in the general population are crucial factors in preventing dengue virus infection[10,11].

A study by Elsinga *et al.* in 2015 in Venezuela emphasized the importance of assessing dengue fever patients' attitudes toward healthcare services[12]. Additionally, raising community knowledge about the severity of efforts to prevent Dengue fever is deemed necessary[9].

One of the challenges associated with dengue fever control is the lack of knowledge, potentially contributing to its evolution into a global pathogen and the occurrence of a pandemic[11,13,14].

Given the increasing prevalence of dengue fever in certain countries[15,16] and the emphasis by the World Health Organization (WHO)[5], as well as research findings[11-14,17] underscoring the importance of knowledge and guidance for recommended actions to control dengue, this study aims to determine the global level of knowledge, attitudes, and practices towards dengue fever among the general population.

2. Materials and methods

As part of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, this study conformed to a set of 27 criteria that should be followed when reporting systematic reviews and meta-analyses to ensure accurate and transparent reporting. These criteria ensure that the study is comprehensive and unbiased, that the methods used are appropriate, and that the data support the conclusions.

2.1. Search strategy

Multiple databases were searched, including Google Scholar, PubMed/MEDLINE, Scopus, Web of Science, Science Direct, Springer, EMBASE, and ProQuest, to locate a variety of publications; additionally, articles published until October 2023 in English were included in the search. Various MeSH phrases were combined with other search terms, including "AND," "OR," and "NOT," to refine the search results and improve their accuracy (Supplementary Table 1). Besides, the references of the identified publications were examined to ensure a comprehensive search. Figure 1 illustrates the PRISMA flowchart for searching and selecting relevant articles.

2.2. Inclusion and exclusion criteria

This study included all cross-sectional studies investigating public knowledge, attitudes, and practices related to dengue as part of the inclusion criteria. All articles published in English and available in full-text format until October 2023 were eligible for consideration, and topics were selected using a random sample method. Articles that did not meet these criteria, including short communications (*e.g.*, non-observational studies) and those focusing on other mosquito-borne viral diseases and a population other than the general population (*e.g.*, students, healthcare providers), were excluded.

2.3. Quality assessment

This review and analysis assessed the reliability of studies using the modified Newcastle–Ottawa Scale (NOS), a joint effort between the University of Newcastle in Australia and the University of Ottawa in Canada. This scale aims to combine quality evaluations into the interpretation of meta-analytic results by evaluating non-randomized studies' design, content, and user-friendliness. Studies are assessed and scored based on three perspectives, each of which includes subsections: selection of the study groups (including representation of the sample, sample size, exposure identification, and non-respondents), ability to compare groups (the subjects in different outcome groups are comparable based on the study design or analysis and confounding factors) and determining the exposure

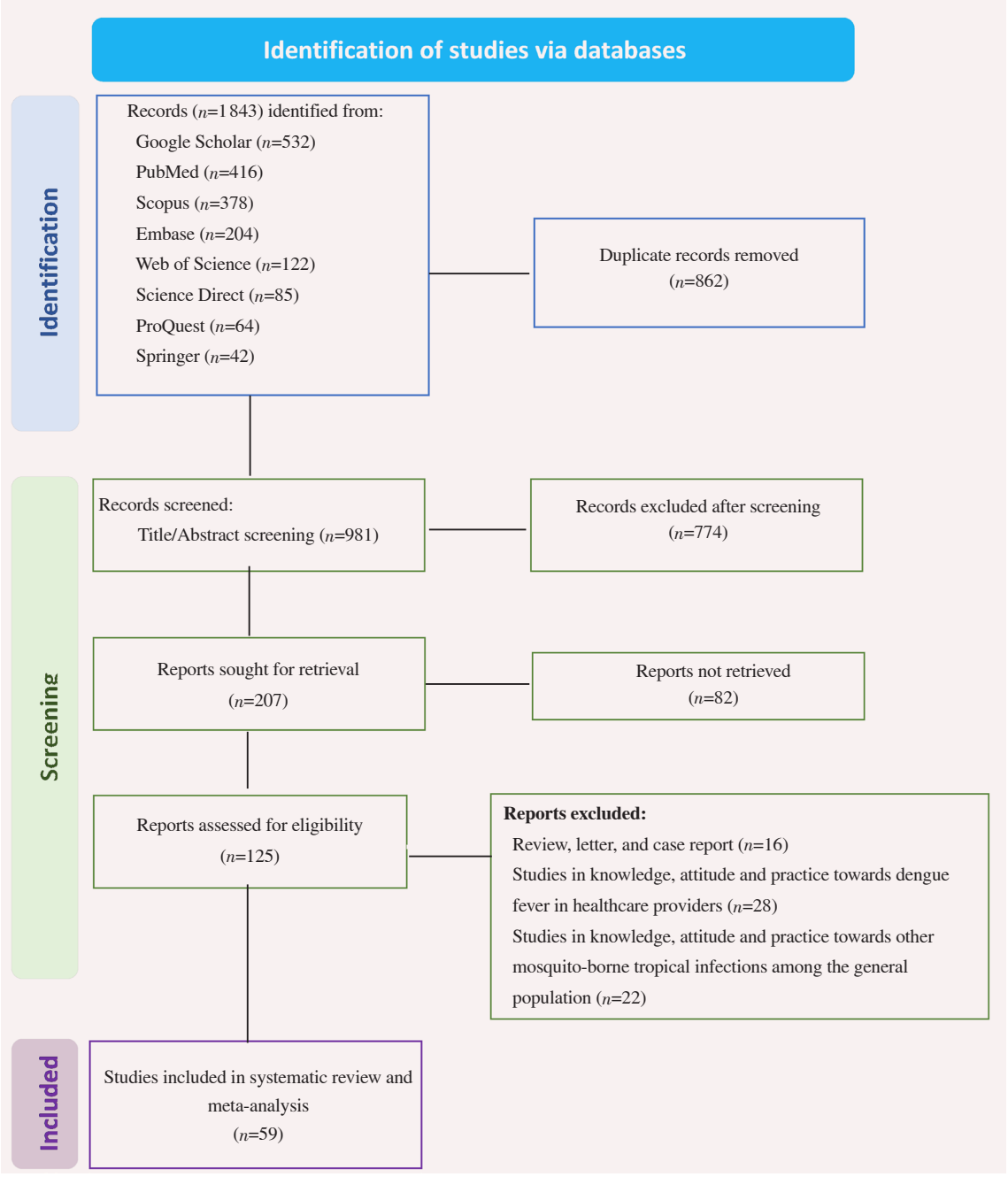

Figure 1. PRISMA flowchart of studies included in this systematic review and meta-analysis.

or outcome of interest (evaluation of the outcome and statistical test). The NOS is a straightforward and convenient tool to assess non-randomized studies in a systematic review.

It is straightforward for reviewers to measure quality assessment based on the journal's title and authors' names. After carefully reading the article, the first referee completed and scored the article's quality assessment checklist. The same steps were done independently by the second referee. A group discussion was held to discuss disagreements. Scores are calculated based on the checklist for each study, with a range of 0 to 10. As a result, we divide articles with low risk (8–10), medium risk (5–7), and high risk (0–5) into three categories.

2.4. Data extraction

This research involved several steps in data extraction, which was carried out with meticulous attention to details. The duplicate entries in EndNote X8 were removed after importing all the articles. Each team member reviewed the titles and abstracts of the remaining publications to remove irrelevant research. Based on reports related to the research issue, the selection criteria followed descriptive and cross-sectional study methods. After identifying relevant articles, a final decision was made by group discussion, the reports were subsequently assessed qualitatively, and information was extracted. Several factors were extracted for analysis, including the author's

name, the year, the type, sample size, geographic location, and the participants' levels of knowledge, attitudes, and practices. In cases where discrepancies arose between the two team members during data extraction, a consensus was reached through discussion and re-evaluation of the respective articles. If disagreements persisted, a third senior researcher was consulted to provide an impartial resolution.

2.5. Ethics approval and consent to participate

We carefully followed ethical guidelines for our systematic review and meta-analysis investigations throughout this research. The Jahrom University of Medical Sciences Ethics Committee officially approved the study protocol, assigning it the code: I.R.JUMS.REC.1402.049.

2.6. Statistical analysis

For this meta-analysis, we used STATA version 14 to conduct statistical analysis. The heterogeneity across the studies was measured using the inverse variance and Cochran *Q* statistics. The degree of heterogeneity was categorized as low, moderate, or high based on the I^2 test statistics. We considered heterogeneity low, moderate, and high when the I^2 value was less than 50%, between 50% and 80%, and greater than 80%, respectively. Due to heterogeneity, we had to utilize the Dersimonian and Liard random-effects models. The one-out-remove method was used in the sensitivity analysis to determine the effect of each research on the outcomes. The included studies were analyzed for heterogeneity using various techniques such as subgroup analysis and univariate meta-regression. Egger's regression was employed in this analysis to assess publication bias. Moreover, the overall estimate was adjusted using the trim-and-fill method to account for any studies that may have been missed due to censorship. The ArcGIS 10.3 software was used to analyze the distribution of knowledge, attitudes, and practices by continent and country.

3. Results

3.1. Eligibility studies and search results

First, out of the present databases, 1 843 articles were chosen based on predetermined inclusion criteria. Afterward, 862 articles considered duplicates were eliminated during the first screening stage. Excluded records: 774 title/abstract screening after this stage, all full-text publications were thoroughly reviewed, and 82 studies were not given any more attention. The meta-analysis comprised 59 research, comprising 29 studies on practice, 33 on attitudes, and 55 on knowledge (Figure 1).

3.2. Features of the eligible studies

The research used 59 journal articles that met the eligibility standards and were chosen from the initial pool of publications. Using the NOS quality evaluation checklist to assess the publications' quality, 51 papers had a low risk of bias and 8 to moderate risk of bias, indicating their methodological robustness (Table 1). There was no evidence of a significant risk of bias in any of the research.

Among the studies included in this meta-analysis, 23 studies were related to the Southeast Asia region, 20 studies were Oceania, six studies were from the Eastern Mediterranean region, five studies were from the Americas, four studies were from Africa, and one study pertained to the European area according to the WHO.

3.3. Pooled good knowledge of dengue fever

A thorough examination of 55 studies with 86 278 participants was done to gauge participants' knowledge of dengue fever. Considering heterogeneity (Ⅰ-Ⅴ heterogeneity), a random-effects model was used to calculate the pooled proportion of good knowledge. 40% (95% *CI* 34%-46%) of the general public knew about dengue fever overall (Figure 2). Yet, there was a notable degree of heterogeneity between the included studies (I^2=99.8%, *Q* statistic=22 150.37, *P*<0.000 1) (Figure 2).

After eliminating the one-by-one studies approach, we conducted a comprehensive sensitivity analysis. The findings showed that no single study significantly affected the proportion of good knowledge; consequently, we could not identify any important studies in this regard.

Univariate meta-regression was used to identify possible sources of the heterogeneity seen in the study. None of the variables, including study quality, WHO region, year, and sample size, are sources of heterogeneity, according to the meta-regression results (*P*>0.05). Nevertheless, country (*B* coefficient=0.001 75, *P*=0.024) may be a possible source of heterogeneity in research about knowledge, according to univariate meta-regression. This means that there may be a significant variation in knowledge of dengue fever across different geographical regions (Table 2).

Based on the subgroup analysis results, the good knowledge regarding dengue fever was 39.3% (95% *CI* 32.9%-45.7%) in men and 41.8% (95% *CI* 34.2%-49.3%) in women.

The highest level of knowledge was in the European region at 63.5% (59.7%-67.3%), while the lowest level of knowledge was in the African region at 20.3% (3.02%-40.80%) (Table 3, Supplementary Figure 1). The good knowledge level in the age group equal or older than 30 years was 48.6% (95% *CI* 35.5%-61.6%), while in the age group younger than 30 years, it was 46.5% (95% *CI* 32.3%-60.7%) (Table 3).

Table 1. Compilation of studies incorporated in this systematic review and meta-analysis.

Authors name	Year of publication	Study region	WHO region	Study design	Sample size	Good knowledge (%)	Good practice (%)	Positive attitude (%)	Study quality
Khan J.[17]	2022	Pakistan	Eastern Mediterranean	Cross-sectional	500	70	NR	40	6
Isa A.[18]	2013	Malaysia	Western Pacific	Cross-sectional	280	40.7	NR	NR	6
Ramzan M.[19]	2015	Pakistan	Eastern Mediterranean	Cross-sectional	413	21.29	NR	NR	7
Al-Dubai S. A.[20]	2013	Malaysia	Western Pacific	Cross-sectional	300	NR	7.7	2.2	7
Rahman M. S.[21]	2020	Bangladesh	Southeast Asia	Cross-sectional	1 500	76.7	39.1	87.9	6
Shuaib F.[22]	2010	Jamaica	America	Cross-sectional	192	54	NR	NR	5
Selvarajoo S.[23]	2020	Malaysia	Western Pacific	Cross-sectional	500	73.2	71.1	70.07	6
Vo T. Q.[24]	2019	Vietnam	Western Pacific	Cross-sectional	1 175	38	55	74	7
Win K. T.[25]	2004	Myanmar	Southeast Asia	Cross-sectional	405	39	NR	NR	6
Castro M.[26]	2013	Cuba	America	Cross-sectional	780	74.3	NR	NR	5
Hairi F.[27]	2003	Malaysia	Western Pacific	Cross-sectional	200	72.6	64.1	NR	6
Nalongsack S.[28]	2009	Lao	Western Pacific	Cross-sectional	230	40.4	NR	NR	5
Rahman M. S.[29]	2021	Lao	Western Pacific	Cross-sectional	360	16.7	17	16.8	6
Rahman M. S.[30]	2021	Thailand	Southeast Asia	Cross-sectional	359	17.7	14.4	13.3	6
Suwanbamrung C.[31]	2021	Thailand	Southeast Asia	Cross-sectional	3 156	12.3	30.8	42.9	6
Yboa B. C.[32]	2013	Philippines	Western Pacific	Cross-sectional	646	61.45	NR	NR	6
Ashok Kumar V.[33]	2001	India	Southeast Asia	Cross-sectional	861	2	NR	NR	5
Firdous J.[34]	2017	Malaysia	Western Pacific	Cross-sectional	86	42.5	NR	NR	6
Harapan H.[35]	2018	Indonesia	Southeast Asia	Cross Sectional	609	23	NR	63.6	6
Gunasekara T. D. C. P.[36]	2012	Sri Lanka	Southeast Asia	Cross-sectional	349	58	81	37	6
Sulistyawati S.[37]	2019	Indonesia	Southeast Asia	Cross-sectional	521	5.3	10.5	29.4	6
Dhimal M.[38]	2014	Nepal	Southeast Asia	Cross-sectional	589	12	37	83	6
Malhotra G.[39]	2013	India	Southeast Asia	Cross-sectional	800	59.25	NR	NR	6
Saied K. G.[40]	2015	Yemen	Eastern Mediterranean	Cross-sectional	804	31.7	NR	40.4	7
AhbiRami R.[41]	2015	Malaysia	Western Pacific	Cross-sectional	203	12.1	NR	10.4	5
Ahmed N.[42]	2008	Maldives	Southeast Asia	Cross-sectional	341	12.6	9		6
Sayavong C.[43]	2015	Vientiane	Southeast Asia	Cross-sectional	207	74.77	NR	54.17	6
Udayanga L.[44]	2018	Sri Lanka	Southeast Asia	Cross Sectional	1 000	40	NR	53.5	6
Sarmiento-Senior D.[45]	2019	Colombia	America	Cross-sectional	206	7.2	6.1	9.5	6

Table 1. Continued.

Authors name	Year of publication	Study region	WHO region	Study design	Sample size	Good knowledge (%)	Good practice (%)	Positive attitude (%)	Study quality
Nguyen P. V.[46]	2019	Viet Nam	Western Pacific	Cross-sectional	2400	37.2	56.1	57.1	6
Kosasih C. E.[47]	2021	Indonesia	Southeast Asia	Cross Sectional	323	9.6	NR	42.1	6
Phuyal P.[48]	2022	Nepal	Southeast Asia	Cross-sectional	600	2.3	21.2	74.1	6
Kazaura M.[49]	2020	Tanzania	African	Cross Sectional	441	NR	47.4	19.2	6
Wan Rosli W. R.[50]	2019	Malaysia	Western Pacific	Cross-sectional	307	26.1	71	88.6	6
Yussof F. M.[51]	2017	Malaysia	Western Pacific	Cross-sectional	870	83.9	81.8	10.6	6
Aung M. M. T.[52]	2016	Malaysia	Western Pacific	Cross-sectional	570	54.6	91.7	18.6	6
Pang J.[53]	2017	Singapore	Western Pacific	Cross-sectional	364	89.9	NR	NR	5
Pang J.[53]	2017	Singapore	Western Pacific	Cross-sectional	364	86	NR	NR	6
AA K. H.[54]	2017	Malaysia	Western Pacific	Cross-sectional	265	53.2	NR	43.4	7
Kamel M.[55]	2017	Malaysia	Western Pacific	Cross-sectional	250	48	54	93	6
Alhoot M. A.[56]	2017	Malaysia	Western Pacific	Cross-sectional	284	60.7	57.3	44	6
Mohammed Yusuf A.[57]	2019	Ethiopia	African	Cross-sectional	348	10.3	NR	NR	5
Sharma B.[58]	2012	Nepal	Southeast Asia	Cross-sectional	204	52	NR	73	6
Kajeguka D. C.[59]	2017	Tanzania	African	Cross-sectional	290	2.4	NR	NR	6
Bhanu Vaishnavi G.[60]	2015	India	Southeast Asia	Cross-sectional	177	0	2.8	1.6	6
Lamaurt F.[61]	2022	France	European	Cross Sectional	622	63	NR	NR	6
Zida-Compaore W. I. C. [62]	2022	Togo	African	Cross Sectional	339	47.1	NR	NR	6
Munir F.[63]	2015	Pakistan	Eastern Mediterranean	Cross-sectional	450	13.11	8.67	NR	6
Mustapha I.[64]	2023	Malaysia	Western Pacific	Cross-sectional	320	16.48	9.29	32	6
Charnchudhi Chanyasanha M.[65]	2013	Thailand	Southeast Asia	Cross-sectional	300	18	NR	NR	6
Kumar V.[66]	2018	India	Southeast Asia	Cross-sectional	212	50.9	NR	NR	6
Fernandez-Guzman D.[67]	2023	Peru	America	Cross Sectional	57829	36.2	11.6	NR	6
Kwon D. H.[68]	2004	Peru	America	Cross-sectional	50	NR	29.2	NR	6
Kyu H. H.[69]	2005	Thailand	Southeast Asia	Cross-sectional	307	44	NR	NR	6
Nikookar S. H.[70]	2023	Iran	Eastern Mediterranean	Cross-sectional	284	NR	81	72.2	7
Sharmila N.[71]	2021	Bangladesh	Southeast Asia	Cross-sectional	193	27.5	34.2	83.9	7
Saghir M. A.[72]	2022	Yemen	Eastern Mediterranean	Cross-sectional	370	53.3	NR	64.1	6
Martina S. E.[73]	2018	Indonesia	Southeast Asia	Cross-sectional	148	46.6	NR	NR	5

NR: not reported.

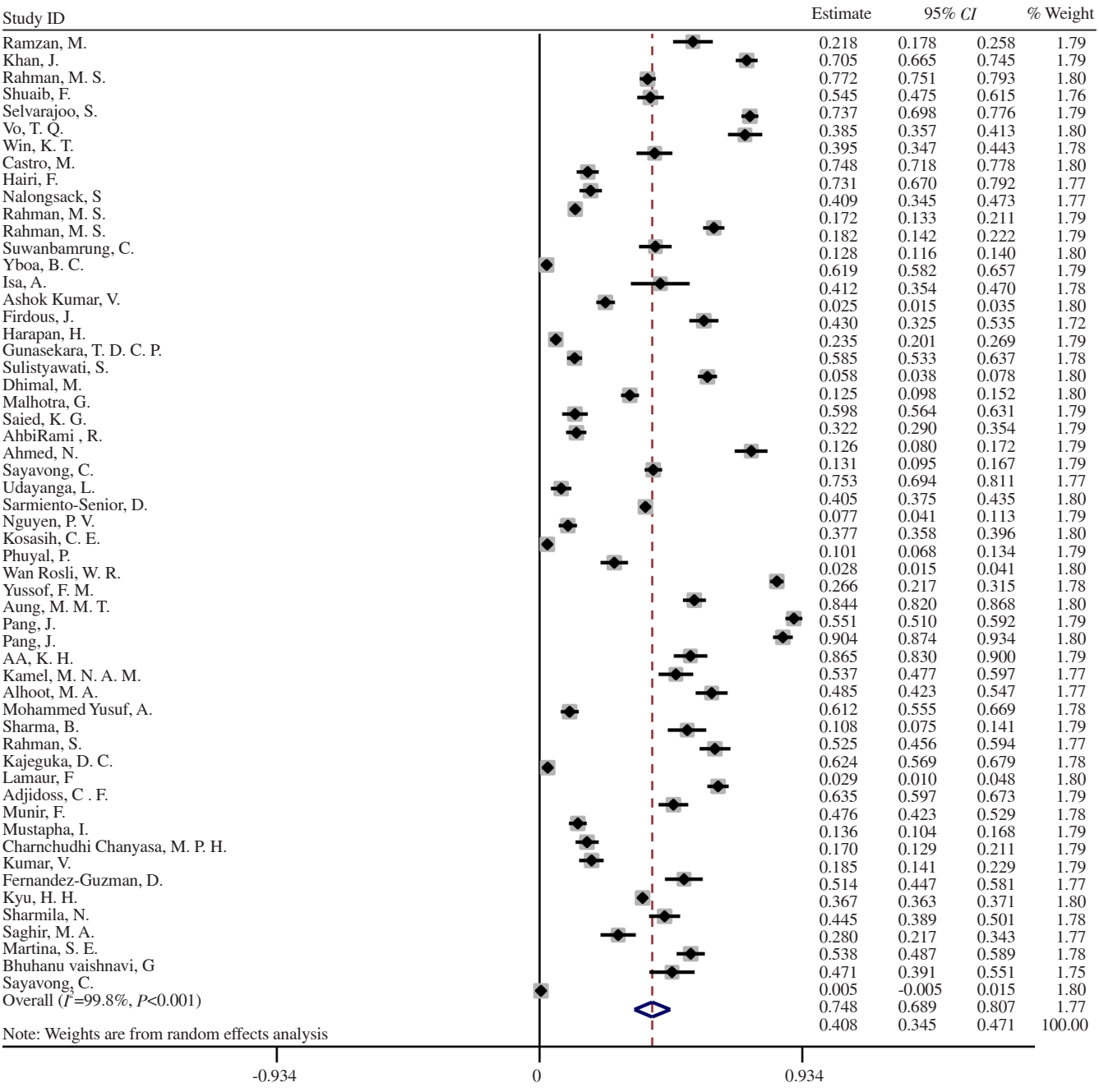

Figure 2. Forest plot for good knowledge of dengue fever using random effect meta-analysis in the general population.

3.4. Pooled good attitudes towards dengue fever

For the attitude analysis, 33 studies involving 20196 participants were evaluated. The percentage of the general population with positive attitudes was 47% (95% *CI* 36%-58%), based on the random effect model with Ⅰ-Ⅴ heterogeneity (Figure 3). Nonetheless, there was a notable degree of heterogeneity between the studies (I^2= 99.8%, *Q* statistic=892.94, *P*<0.000 1).

We removed the one-by-one studies method from our thorough sensitivity analysis, and the results showed that no single study had a significant impact on the proportion of good attitudes. As a result, the analysis did not identify any influential studies in this regard.

The study employed univariate meta-regression to ascertain potential causes of the observed heterogeneity. The meta-regression results show that none of the factors (year, sample size, and research quality) are sources of heterogeneity (*P*>0.05). However, univariate meta-regression indicates that WHO Reign (*B* coefficient=0.068 5, *P*=0.045) can potentially cause variation in attitude research (Table 2).

The results of subgroup analysis revealed that the highest level of positive attitude was observed in the Eastern Mediterranean 54.1% (38.5%-69.7%) and Southeast Asia 53.6% (34.2%-73.0%) regions,

while the lowest level was found in the Americas 9.05% (5.05%-13.5%). In addition, the attitude level was highest in Bangladesh, 86.7% (83.1%-90.3%), and lowest in India,1.06% (0.02%-3.04%) (Table 3, Supplementary Figure 2). The level of positive attitude was 42.2% (15.6%-68.8%) in men and 45.2% (17.5%-72.9%) in women. In the age group equal or older thann30 years, this level was 47.4% (18.4%-76.5%), while in the age group under 30 years, it was 26.9% (14.1%-39.8%) (Table 3).

3.5. Dengue fever preventive behaviors

For the attitude analysis, 29 studies involving 74 881 participants were evaluated. The percentage of the general population with dengue fever preventive behaviors was 38.3% (95% *CI* 28.4%-48.2%), based on the random effect model with Ⅰ-Ⅴ heterogeneity (Figure 4). Nonetheless, there was a notable degree of heterogeneity between the studies (I^2= 99.8%, *Q* statistic=14 933.26, *P*<0.000 1).

Our sensitivity analysis, when the one-by-one studies procedure was eliminated, revealed that no single study significantly affected the preventive behaviors of dengue fever. The study employed univariate meta-regression to ascertain potential causes of the observed heterogeneity. The meta-regression results show that none of the variables (year, region, sample size, and research quality) are sources of heterogeneity (*P*>0.05). However, nation (*B* coefficient=0.016 31, *P*=0.023) can potentially cause variation in studies concerning dengue fever preventive behaviors. This suggests that there may be significant differences in dengue fever prevention practices across different geographic regions (Table 2).

The findings of subgroup analysis showed that the prevalence of preventive behaviors for dengue fever in the following regions: Americas 12.1% (6.0%-18.2%), Southeast Asia 28.1% (16.3%-39.9%), Western Pacific 49.6% (32.2%-67.0%), Eastern Mediterranean 44.8% (26.1%-95.7%), and Africa 47.4% (42.7%-52.1%) (Table 3, Supplementary Figure 3). Furthermore, these behaviors were observed in urban residents at 41.8% (26.1%-57.4%) and in rural areas at 46.8% (1.06%-92.00%). The rate of desirable preventive behaviors was 34.7% (6.07%-62.70%) in men and 36.7% (10.0%-63.3%) in women (Table 3).

3.6. Publication bias

According to Egger's test, there was no discernible publication bias in the knowledge-related papers included in this meta-analysis (bias=5.180, 95% *CI* -2.39 to 12.751, *P*=0.176). The study's strong results were further supported by the symmetric distribution of studies in the funnel plot analysis (Figure 5A), which did not suggest the existence of publication bias.

Furthermore, Egger's test revealed that the studies on attitudes included in this meta-analysis did not exhibit significant publication bias (bias=7.386, 95% *CI* -11.10 to 25.87, *P*=0.421). The results of the study were further supported by the symmetric distribution of studies in the funnel plot analysis (Figure 5B), which did not support the existence of publication bias.

The Egger's regression test and the irregularity in the funnel plot demonstrated notable publication bias within the studies encompassing practice that was incorporated in this meta-analysis (bias=16.02, 95% *CI* 7.45-24.60, *P*=0.001) (Figure 5C). A non-parametric Trim-and-fill model was applied to rectify this bias, revealing an estimation of 11 hypothetical studies regarding the practice of dengue fever among the general population that could be absent from the meta-analysis. Utilizing this technique, the adjusted pooled proportion of good practice, determined through the random effects model, was appraised at 15.5% (95% *CI* 5.01%-25.90%).

Table 2. Univariate meta-regression is used to identify potential reasons for study heterogeneity.

Type	Possible cause of heterogeneity	Meta-regression coefficient (95% *CI*)	*P* value
Knowledge	Quality of study	-0.030 (-0.172, 0.111)	0.671
	Country	0.001 (0.001, 0.008)	0.024
	Year of publication	-0.002 (-0.015, 0.010)	0.706
	Sample size	-0.000 (-0.000, 0.000)	0.881
	WHO region	0.007 (-0.048, 0.064)	0.784
Attitude	Quality of study	0.114 (-0.113, 0.341)	0.313
	WHO region	0.068 (0.051, 0.078)	0.045
	Country	-0.002 (-0.027, 0.022)	0.819
	Year	0.012 (-0.017, 0.042)	0.406
	Sample size	0.000 (-0.000, 0.000)	0.740
Practice	Quality of study	0.071 (-0.242, 0.386)	0.643
	Country	0.016 (0.012, 0. 047)	0.023
	Year	-0.007 (-0.031, 0.015)	0.507
	Sample size	0.000 (0.000, 0.000)	0.378
	WHO region	0.036 (-0.063, 0.137)	0.460

Table 3. The results of the subgroup analysis for the general population's knowledge, attitude, and practice regarding dengue fever.

Type		Grouping	No. studies	No. examined	Overall frequency (95 *CI*) (%)	Heterogeneity			
						χ^2	*P*-value	I^2 (%)	Tau-squared
Knowledge	Sex	Male	10	35422	39.3 (32.9-45.7)	867.79	<0.001	99.0	0.009
		Female	10	36545	41.8 (34.2-49.3)	1366.02	<0.001	99.3	0.014
	WHO Region	Eastern Mediterranean	5	2537	38.3 (18.1-58.6)	575.03	<0.001	99.3	0.053
		Southeast Asia	22	13254	30.9 (21.9-39.9)	6611.81	<0.001	99.7	0.046
		Americas	4	59007	43.4 (20.0-66.8)	771.21	<0.001	99.7	0.056
		Western Pacific	20	9881	51.9 (40.6-63.3)	7895.12	<0.001	99.4	0.066
		African	3	977	20.3 (3.02-40.8)	1366.07	<0.001	99.2	0.032
		European	1	622	63.5 (59.7-67.3)	NA	NA	NA	NA
	Country	Pakistan	3	1363	35.3 (12.0-69.4)	510.98	<0.001	99.6	0.090
		Bangladesh	3	1993	56.0 (28.7-83.3)	219.22	<0.001	99.1	0.057
		Jamaica	1	192	54.5 (47.5-61.5)	NA	NA	NA	NA
		Malaysia	12	4135	49.2 (33.5-64.9)	1512.81	<0.001	99.3	0.075
		Vietnam	2	3575	38.0 (36.4-39.6)	0.21	0.644	0.0	0.000
		Myanmar	1	405	39.5 (34.7-44.3)	NA	NA	NA	NA
		Cuba	1	780	74.8 (71.8-77.8)	NA	NA	NA	NA
		Laos	4	1004	52.0 (21.1-82.9)	395.02	<0.001	99.2	0.098
		Thailand	4	4122	23.3 (12.2-34.3)	126.42	<0.001	97.6	0.012
		Philippines	1	646	61.9 (58.2-65.7)	NA	NA	NA	NA
		India	4	2050	28.3 (11.0-45.5)	1273.01	<0.001	99.8	0.030
		Indonesia	4	1601	21.0 (8.09-33.20)	155.71	<0.001	98.1	0.014
		Sri Lanka	2	1349	49.4 (31.7-67.0)	34.59	<0.001	97.1	0.015
		Nepal	3	1393	22.1 (5.01-39.10)	222.19	<0.001	99.1	0.022
		Yemen	2	1174	42.9 (21.7-64.1)	49.46	<0.001	98.0	0.022
		Maldives	1	341	13.1 (9.05-13.7)	NA	NA	NA	NA
		Colombia	1	206	7.07 (4.01-11.10)	NA	NA	NA	NA
		Singapore	2	728	88.6 (84.7-92.4)	2.72	0.099	63.2	0.000
		Ethiopia	1	348	10.8 (7.05-14.10)	NA	NA	NA	NA
		Tanzania	1	731	2.09 (0.01-4.08)	NA	NA	NA	NA
		France	1	622	63.5 (59.7-67.3)	NA	NA	NA	NA
		Togo	1	339	47.6 (42.3-52.9)	NA	NA	NA	NA
		Peru	1	57829	36.7 (36.3-37.1)	NA	NA	NA	NA
	Age group	≥30 years	9	40303	48.6 (35.5-61.6)	459.83	<0.001	98.3	0.038
		<30 years	8	20635	46.5 (32.3-60.7)	388.51	<0.001	98.2	0.040
	Place	City	14	10821	45.8 (29.7-61.9)	7361.47	<0.001	99.8	0.094
		Villages	9	3815	45.0 (33.4-56.6)	577.26	<0.001	98.6	0.036
		Island	1	192	54.0 (47.0-61.0)	NA	NA	NA	NA
Attitude	WHO Region	Eastern Mediterranean	4	1958	54.1 (38.5-69.7)	153.29	<0.001	98.0	0.024
		Southeast Asia	12	9257	53.6 (34.2-73.0)	6180.35	<0.001	99.8	0.117
		Americas	1	206	9.05 (5.05-13.50)	NA	NA	NA	NA
		Western Pacific	15	8334	43.8 (26.7-60.9)	6263.06	<0.001	99.8	0.113
		African	1	441	19.2 (15.5-22.9)	NA	NA	NA	NA
	Country	Malaysia	10	3869	41.3 (18.7-63.7)	4524.15	<0.001	99.8	0.132
		Pakistan	1	500	40.0 (35.7-44.3)	NA	NA	NA	NA

Table 3. Continued.

Type		Grouping	No. studies	No. examined	Overall frequency (95 *CI*) (%)	Heterogeneity			
						χ^2	*P*-value	I^2 (%)	Tau-squared
		Bangladesh	2	1693	86.7 (83.1-90.3)	0.15	0.150	51.8	0.000
		Vietnam	2	3575	65.5 (49.0-82.1)	107.45	<0.001	99.1	0.014
		Laos	3	774	41.6 (13.8-69.4.0)	141.36	<0.001	98.6	0.059
		Thailand	2	3515	28.1 (9.0-57.1)	219.69	<0.001	99.5	0.043
		Indonesia	3	1453	45.0 (23.3-65.8)	152.66	<0.001	98.7	0.036
		Sri Lanka	2	1349	45.4 (29.2-61.5)	29.70	<0.001	96.6	0.013
		Nepal	3	1393	77.0 (70.1-83.8)	17.63	<0.001	88.7	0.003
		Yemen	2	1174	52.02 (29.00-75.40)	60.96	<0.001	98.4	0.027
		Colombia	1	206	9.05 (5.05-13.50)	NA	NA	NA	NA
		Tanzania	1	441	19.2 (15.5-22.9)	NA	NA	NA	NA
		India	1	177	1.06 (0.02-3.04)	NA	NA	NA	NA
		Iran	1	284	72.2 (67.0-77.4)	NA	NA	NA	NA
	Age group	≥30 years	6	1704	47.4 (18.4-76.5)	1335.58	<0.001	99.6	0.131
		<30 years	6	780	26.9 (14.1-39.8)	104.81	<0.001	95.2	0.023
	Sex	Male	6	829	42.2 (15.6-68.8)	585.40	<0.001	99.1	0.109
		Female	6	1493	45.2 (17.5-72.9)	1047.28	<0.001	99.5	0.118
Practice	WHO reign	Eastern Mediterranean	2	734	44.8 (26.1-95.7)	728.78	<0.001	99.9	0.261
		Southeast Asia	10	7744	28.1 (16.3-39.9)	1469.19	<0.001	99.4	0.035
		Americas	3	58085	12.1 (6.0-18.2)	18.33	<0.001	89.1	0.002
		Western Pacific	13	7877	49.6 (32.2-67.0)	4482.41	<0.001	99.7	0.101
		African	1	441	47.4 (42.7-52.1)	NA	NA	NA	NA
	Country	Malaysia	9	3601	56.4 (32.3-80.6)	3214.92	<0.001	99.8	0.136
		Bangladesh	3	1993	27.9 (7.07-48.20)	172.82	<0.001	98.8	0.031
		Vietnam	2	3575	55.7 (54.1-57.4)	0.39	0.534	0.0	0.000
		Laos	1	360	17.0 (13.1-20.9)	0.00	NA	NA	NA
		Thailand	2	3515	22.70 (6.06-38.80)	65.46	<0.001	98.5	0.013
		Sri Lanka	1	349	81.0 (76.9-85.1)	0.00	NA	NA	NA
		Indonesia	1	521	10.50 (7.09-13.10)	0.00	NA	NA	NA
		Nepal	2	1189	29.1 (13.6-44.5)	37.03	<0.001	97.3	0.012
		Maldives	1	341	0.09 (0.06-12.00)	0.00	NA	NA	NA
		Colombia	1	206	6.01 (2.08-9.04)	NA	NA	NA	NA
		Tanzania	1	441	47.4 (42.7-52.1)	NA	NA	NA	NA
		India	1	177	2.08 (0.041-5.02)	NA	NA	NA	NA
		Pakistan	1	450	8.07 (6.01-11.3)	NA	NA	NA	NA
		Peru	2	57879	19.2 (2.01-36.3)	7.49	0.006	86.6	0.013
		Iran	1	284	81.0 (76.4-75.6)	NA	NA	NA	NA
	Age group	≥30 years	4	1195	27.90 (5.04-50.00)	306.50	<0.001	99.0	0.052
		<30 years	4	283	22.0 (8.07-35.30)	27.35	<0.001	89.0	0.015
	Sex	Male	4	581	34.7 (6.07-62.70)	265.77	<0.001	98.9	0.072
		Female	4	928	36.7 (10.0-63.3)	0.08	<0.001	99.3	0.081
	Place	City	6	6673	41.8 (26.1-57.4)	872.53	<0.001	99.4	0.037
		Villages	4	1489	46.80 (1.06-92.00)	1831.37	<0.001	99.8	0.212

NA: not available.

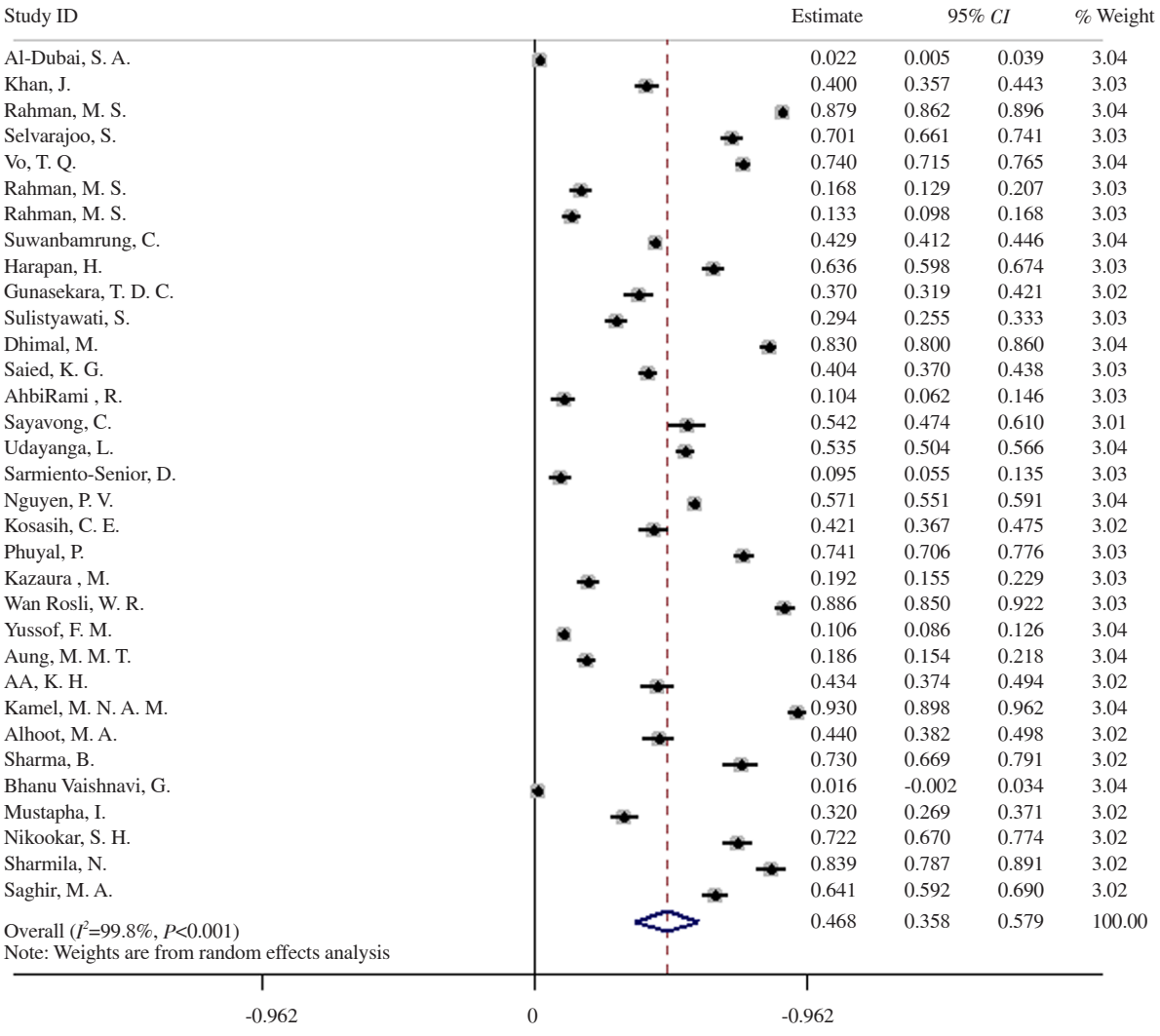

Figure 3. Forest plot for good knowledge of dengue fever using random effect meta-analysis in the general population.

4. Discussion

This study's results showed that the levels of good knowledge, positive attitudes, and dengue fever preventive behaviors among general population were calculated as 40.1%, 46.8%, and 38.3%, respectively. Tailoring public health interventions to address these factors is crucial for enhancing knowledge, fostering positive attitudes, and promoting effective preventive behaviors, ultimately contributing to dengue fever control on a global scale.

The overall knowledge level of the general public regarding dengue fever was moderate, with the highest level of knowledge observed in the European region at 63.5% and the lowest in the African region at 20.3%. There are a number of reasons for the significant differences in the geographical distribution of knowledge of dengue fever. One significant variable is the disparity in healthcare infrastructure; areas with developed healthcare systems, frequently have better public health campaigns and information dissemination, which raises awareness of dengue fever. Disparities in educational resources and accessibility are also important factors. Higher literacy rates and educational levels are characteristics of developed nations, which are also likely to carry out more successful educational programs that raise public knowledge of dengue fever. Furthermore, knowledge levels may vary depending on the geographic incidence of dengue fever. Due to a lack of resources or other factors, regions with a historically higher incidence of dengue, like some parts of Africa, may have trouble spreading information.

The results of the study about level of knowledge are consistent with other research on dengue fever knowledge. For instance, a study conducted in a dengue hotspot in Malaysia revealed that only half of the participants had good knowledge (50.7%) about dengue

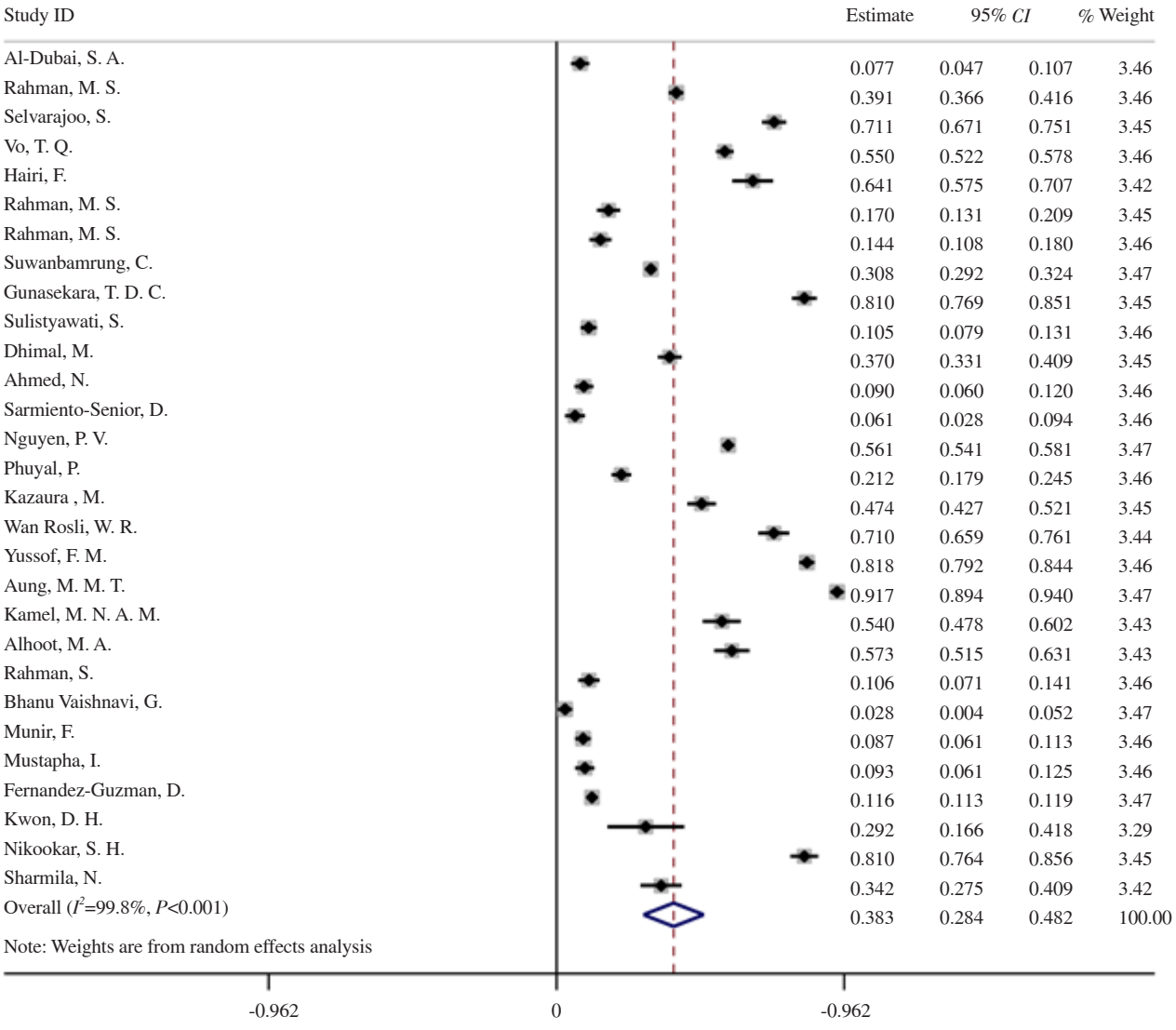

Figure 4. Forest plot for good knowledge of dengue fever using random effect meta-analysis in the general population.

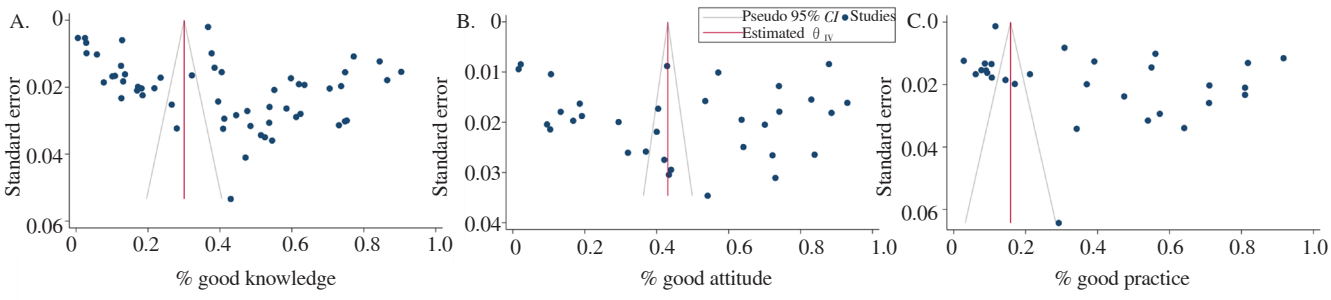

Figure 5. Forest plot for good knowledge of dengue fever using random effect meta-analysis in the general population.

fever. Similarly, a study in Yemen demonstrated that the community's knowledge, toward dengue fever were influenced by factors such as misconceptions about the disease and the timing of mosquito bites[23]. Also, a study conducted in Iran found that although most participants knew about dengue fever, they had less knowledge about dengue symptoms (52%) than about prevention and control (69%), transmission (72.2%), and clinical management (81%)[70].

Additionally, a study in Singapore compared knowledge, attitudes, and practices scores between sustained hotspots and non-sustained hotspots for dengue fever[53]. Dengue infection is asymptomatic in more than 50% of cases, increasing the chance of transmission. Symptomatic patients can also be mistaken for flu-like illnesses or febrile illnesses such as malaria. On the other hand, currently, there is no cure for dengue infection[74,75]. Therefore, increasing people's knowledge about the disease is deemed indispensable.

Over 125 nations have an endemic case of dengue fever, with tropical and subtropical regions like Southeast Asia, Latin America, and parts of Africa being the most affected. *Aedes* mosquitoes are the disease's primary vector and are present in urban and semi-urban settings. Dengue is a major worldwide health concern, as it is endemic in over 100 countries throughout multiple WHO regions, such as Africa, the Americas, the Eastern Mediterranean, South-East Asia, and the Western Pacific[76]. Dengue infections are most common in Asia, accounting for around 70% of all cases worldwide[77,78]. The lowest level of good knowledge was for the African continent, which is alarming despite the relatively high disease prevalence in this region[79]. In the Southeast Asia region, which has a high disease prevalence, a wide range of knowledge levels towards dengue fever was reported[33,37,38]. These cases show the need for international and coordinated planning to increase the population's knowledge about the disease.

Examining attitudes towards dengue fever revealed that approximately half of the general population expressed a positive outlook. However, significant heterogeneity across regions and countries emphasizes the necessity for tailored interventions to determine the degree of attitude consistency and favorability toward dengue prevention[80]. The findings indicated the highest level of positive attitude in the Eastern Mediterranean and Southeast Asia regions, while the American continent exhibited the lowest level. This variability can be attributed to the historical context and prevalence of the disease in these respective regions.

One of the lowest[60] and highest[21] levels of attitude can be seen in the studies related to the East Asian region. This heterogeneity of the attitude level of the population is worrying and can indicate uncoordinated intervention measures at the level of this region and the world.

The results highlight the significance of focused public health initiatives and educational initiatives to dispel myths and enhance dengue fever prevention methods. Interventions that are tailored to certain nations and areas can improve people's attitudes and encourage adherence to self-care practices in the fight against this illness.

Since creating a good attitude is necessary to move people to take effective action[81], elevating individuals' attitudes can significantly enhance their adherence to self-care measures against this disease. The results indicate that the level of good attitude towards dengue fever varies across different age groups. In the age group over 30 years, the level of good attitude was 47.4%, while in the age group under 30 years, it was 26.9%. This disparity in attitude levels between age groups may be associated with the level of knowledge, as the lack of effective educational programs and the prominence of other diseases such as COVID-19 and influenza can influence attitudes towards dengue fever, especially among the younger population. This underscore the importance of tailored interventions and educational programs to address the varying levels of attitude consistency and favorability toward dengue prevention across different age groups and populations.

The global prevalence of dengue preventive practices in the general population was found to be low, with a prevalence of 38.3% based on the assessment of 29 studies covering nearly 75 000 participants. The diverse regional practices and demographic differentials underscore the necessity of tailoring public health strategies to effectively promote and sustain dengue prevention behaviors worldwide.

The highest prevalence of preventive behaviors was in Malaysia, from Southeast Asia region[51,52]. In general, the results showed that preventive behaviors for dengue fever in the Western Pacific, Eastern Mediterranean, and African regions have a higher relative prevalence, which is somewhat consistent with the frequency of the level of good attitude.

A study on public knowledge, attitudes, and practices towards dengue revealed an association between insufficient knowledge, negative attitudes, and inadequate preventive activities. To improve dengue preventive practices, addressing both knowledge and attitudes is crucial. The study's regression results demonstrated significant associations between insufficient knowledge, negative attitudes, and poor preventive behaviors[82]. Furthermore, research have highlighted the role of education, race, and socioeconomic level in influencing dengue knowledge, attitude, and practices, as well as the necessity of converting positive knowledge and attitudes into successful preventative measures[23].

This results emphasize the significance of addressing knowledge and attitude-related issues in order to improve dengue prevention measures worldwide.

There are limitations. Firstly, since we only considered studies that

were published in English, it's possible that we overlooked pertinent papers written in other languages, which could have introduced bias and limited the applicability of our findings. We urge more studies published in languages other than English to be included in future research to take a more inclusive approach.

Second, our ability to generalize our findings may have been hampered by the significant variability among the studies we looked at. We tried to identify the cause of this disparity using statistical techniques, but significant confounding factors were likely missed. We advise creating and sharing recommendations with researchers working on dengue fever studies. Stress using standardized survey questions, research methods, and data collection instruments.

Third, studies with statistically significant or favorable outcomes may have been more likely to be published, even though we used statistical tests to check for publication bias. This could have an impact on our overall findings. Before beginning any research, we strongly advise investigators to pre-register their investigations in open databases.

In conclusion, these findings collectively highlight the nuanced nature of dengue-related knowledge, attitude and practices across different populations. The observed disparities underscore the importance of targeted public health campaigns, emphasizing not only the transmission of knowledge but also the cultivation of positive attitudes and the adoption of effective preventive practices. It is also necessary to take intervention measures at the international level regarding the endemic and prevalent disease areas and pay more attention to improving young people's knowledge, attitudes, and preventive behaviors. A comprehensive, global approach is imperative to address the multifaceted challenges posed by dengue fever and enhance global public health resilience.

Conflict of interest statement

We declare that we have no relevant conflicts of interest.

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Authors' contributions

ASJ, MJ, AA, NS, and TA contributed to both data curation and investigation. ASJ, MJ, AA, and VR contributed to the methodology. ASJ and VR both contributed to writing, reviewing, and editing the manuscript. Moreover, MJ, AA, and VR contributed to formal analysis. MJ, AA, NS, TA, and VR contributed to writing the original draft. VR was involved in project administration and supervision.

Data availability

The authors acknowledge that the data in the article and its appendices are sufficient to substantiate the conclusions drawn from this study.

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