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# Evaluating the effectiveness of dengue surveillance in the tropical and sub-tropical Asian nations through dengue case data from travelers returning to the five Western Pacific countries and territories

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ABSTRACT

*Introduction:* Dengue, affecting over 3.9 billion people, is a significant health threat globally. Despite a tenfold increase in reported cases from 2000 to 2020, underreporting remains an issue. Our study utilized traveler data from the five Western Pacific countries and territories as sentinel sites, to examine dengue surveillance in Southeast and South Asia.
*Methods:* We reported dengue cases among returning travelers (2010–2018) and computed dengue incidence per 100,000 travelers for each destination country. We compared officially reported dengue incidence per 100,000 inhabitants of the destination country with estimated incidence per 100,000 travelers, using Pearson's correlation coefficient.
*Results:* Key findings revealed eight Southeast and South Asia countries as popular destinations for our sentinel sites, with Australia exhibiting the highest incidence (40.7 per 100,000 travelers). Dengue incidence variations were evident, with Malaysia showing a sharp increase over time. Correlation analysis showed strong links in Malaysia ($r$ = 0.66–0.92) and weaker connections in India ($r$ = −0.54–0.76) between dengue incidence among inhabitants and travelers.
*Conclusion:* Systematically collected dengue surveillance data from returning travelers can serve as a proxy for dengue incidence in the destination country and can be used to assess the robustness of the country's dengue surveillance.

## 1. Introduction

Dengue, a prevalent mosquito-borne viral infection, is endemic in over a hundred nations across five of six World Health Organization (WHO) regions [1]. Approximately 3.9 billion people reside in dengue-prone countries, primarily in Southeast and South Asia, the Pacific Islands, and Latin America [2]. Over the past two decades, global dengue cases have increased tenfold, rising from 500,000 in 2000 to 5.2 million in 2020, according to WHO [3]. This upward trend aligns with the emergence and widespread distribution of dengue vectors like *Aedes (Stegomyia) albopictus* and *A. aegypti*, which are primary carriers of dengue to humans in many endemic areas worldwide [4].

Surveillance is crucial for understanding the transmission dynamics of dengue and potential outbreaks. An accurate estimation of infected cases is pivotal in determining the magnitude of dengue epidemics [5]. However, figures reported to WHO through national disease surveillance may not truly represent real-world infections. This discrepancy arises because a large portion of dengue infections either show no symptoms or display mild symptoms that individuals can manage without seeking medical attention [6]. Moreover, in areas lacking proper diagnostic services, misidentification of dengue, especially due to overlapping symptoms with infections like chikungunya or Zika, further skews reported figures downward [7].

In the 21st century, the aviation industry has experienced rapid growth, leading to a surge in international travel. Notably, citizens from high-income nations increasingly visit tropical regions where dengue is

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prevalent. The rising risk of importing dengue into non-endemic areas with dengue vectors, particularly seen in autochthonous transmission cases in southern Europe [4], underscores the need for heightened awareness. Recognizing that infected travelers can introduce dengue viruses to new regions, surveillance has shifted focus to evaluating imported dengue in returning travelers to assess the risk in non-endemic areas [8]. In Europe, initiatives such as the European Network for Tropical Medicine and Travel Health (TropNet) play a crucial role in this surveillance effort [4]. Although many Western Pacific countries have robust dengue surveillance measures [9], providing data on confirmed cases among returning travelers [10,11], there is currently no regional collaboration to compile travel-associated dengue cases.

Here, we conducted a retrospective sentinel site surveillance of international travelers with confirmed dengue infections, focusing on five countries in the Western Pacific region: Australia, Japan, the Republic of Korea (Korea), Taiwan, and Singapore (hereafter WP5). Through this initiative, we aimed to assess the effectiveness of dengue surveillance systems in eight Southeast and South Asian countries frequently visited by residents of these nations. Our evaluation involved comparing officially reported dengue cases in these Asian destinations with estimated dengue incidences among travelers returning from these areas, presumed to have contracted the infection during their stay. We hypothesized that monitoring dengue cases in travelers returning from areas with limited surveillance to these five sentinel sites could uncover potential gaps escaping detection in destination countries.

## 2. Material and methods

### 2.1. Data collection

We selected the WP5—as sentinel sites for travelers' data collection, based on their gross national income levels and the availability of dengue surveillance data among returning travelers. Considering the geographic characteristics of the sentinel site countries and their travel patterns, we initially reviewed 14 preferred Southeast and South Asian countries and ultimately selected eight popular destination countries for further analysis.

Outbound traveler figures for the five sentinel sites to Southeast Asian and South Asian destination countries for 2010–2018 were retrieved from the official tourism statistics. For Southeast Asia, we examined ten countries: Cambodia, Indonesia, Lao P.D.R., Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, and Vietnam. Additionally, we reviewed four South Asian countries: Bangladesh, India, the Maldives, and Sri Lanka. In cases where statistics on travelers by destination country were unavailable, we utilized statistics on visitors from the destination country.

Regarding the official notification of overseas-acquired dengue cases in the WP5, data sources vary across regions, but mostly from the official notifiable diseases surveillance reports. For the annual dengue cases notification in eight popular Southeast Asian and South Asian destination countries, data from Cambodia, Malaysia, the Philippines, Vietnam, Myanmar, India, Indonesia, and Thailand were primarily sourced from each country's official channels. In instances where obtaining the original data proved challenging, WHO-reported data served as supplementary data source in Supplementary Appendix A. To ensure meaningful comparison of dengue incidence across countries visited by each sentinel site, we required enough travelers. Therefore, we excluded countries from our target list of fourteen if fewer than 10,000 travelers from each sentinel site visited the country annually.

### 2.2. Statistical analysis

To compare annual dengue incidences in travelers returning to the WP5 with officially reported incidences in eight Southeast Asian and South Asian destination countries, we calculated dengue incidence per 100,000 travelers from 2010 to 2018. We then compared this traveler-based incidence with reported incidences per 100,000 inhabitants at each destination using the Pearson correlation coefficient. We visualized and compared the dengue incidence by destination in each WP5. The length of the bar graph represents the range of dengue incidence rates in each country visited by travelers from each sentinel site over the nine years (2010–2018), while the center dot indicates the mean. Due to varying lengths of stay for travelers from each WP5, it was challenging to directly compare absolute values; thus, we categorized them according to the destinations visited.

## 3. Result

Fig. 1 illustrates the percentage distribution of dengue cases among travelers from the WP5 who visited 14 Southeast Asian and South Asian countries. The majority (57.4 %) of dengue cases among travelers returning to Australia originated from Indonesia, followed by Thailand (11.0 %), India (7.3 %), the Philippines (5.3 %), Sri Lanka (5.0 %), and Malaysia (4.8 %). For travelers returned to Japan, 25.8 % of dengue cases were linked to Indonesia, trailed by the Philippines (23.0 %), Thailand (12.3 %), India (10.5 %), Malaysia (6.6 %), and Vietnam (5.7 %). In the case of travelers returning to Korea, 90 % of dengue cases were contracted in Southeast Asian countries, with the Philippines contributing 35.9 %, followed by Thailand (13.7 %), Indonesia (12.1 %), Vietnam (9.5 %), and Malaysia (5.9 %). Singapore, located at the tip of the Malay Peninsula, reported that most dengue cases were associated with visits to Indonesia (37.5 %), Malaysia (27.9 %), India (10.8 %), Thailand (6.7 %), and the Philippines (5.3 %). In Taiwan, a subtropical region, 95 % of dengue cases were linked to tropical Asian trips, with Indonesia leading at 21.7 %, followed by the Philippines (17.5 %), Vietnam (16.9 %), Malaysia (12.9 %), Thailand (12.2 %), and Cambodia (6.0 %). Based on these findings, eight of the originally 14 considered travel destinations were identified, including seven from Southeast Asian countries and one from South Asian countries.

Table 1 summarizes the combined dengue case counts reported by travelers who returned from eight popular Southeast and South Asian countries to the WP5 from 2010 to 2018. Australia accounted for over half of these cases, exhibiting the highest incidence at 40.7 per 100,000 travelers. Additionally, the average trip duration for Australian travelers was nearly double that of counterparts from the other four nations and territories. Annually, it is estimated that approximately 1.04 million travelers from Australia visit Indonesia, accounting for 39 % of all Australian travelers to the eight selected countries. These travelers experienced the highest dengue incidence, averaging 66.6 cases per 100,000 travelers over the past nine years (Fig. 2). The dengue incidence among Japanese travelers was 4.7 cases per 100,000. The highest incidence for Japanese travelers occurred in Indonesia, with 10.5 cases per 100,000 (Fig. 2). In Thailand, which accounted for 35 % of Japanese travelers, the incidence was 1.8 cases per 100,000. Korean travelers experienced a dengue incidence of 3.2 cases per 100,000. Among the destinations visited, Myanmar had the highest incidence for Korean travelers, with 10.3 cases per 100,000. Their travel patterns were similar to the Philippines, Thailand, and Vietnam, each representing 25 % of their travel destinations. The dengue incidence rates were 5.2, 1.9, and 1.3 cases per 100,000, in the Philippines, Thailand, and Vietnam, respectively. Singaporean travelers had a dengue incidence of 1.7 cases per 100,000. India had the highest dengue incidence among their destinations, with 21.2 cases per 100,000. In Malaysia, which comprised 81 % of all travelers, the incidence was only 0.6 cases per 100,000. Excluding Malaysia, where most travelers were daily commuters, the incidence was 6.3 cases per 100,000. Taiwanese travelers reported a dengue incidence of 16.3 cases per 100,000. Myanmar had the highest incidence for Taiwanese travelers, with 56.8 cases per 100,000. Among Taiwanese travelers to Thailand, which accounted for 30 % of all travelers, the incidence was 7.1 cases per 100,000.

The yearly dengue incidence, whether estimated for travelers or officially reported, varied across the top eight destination countries

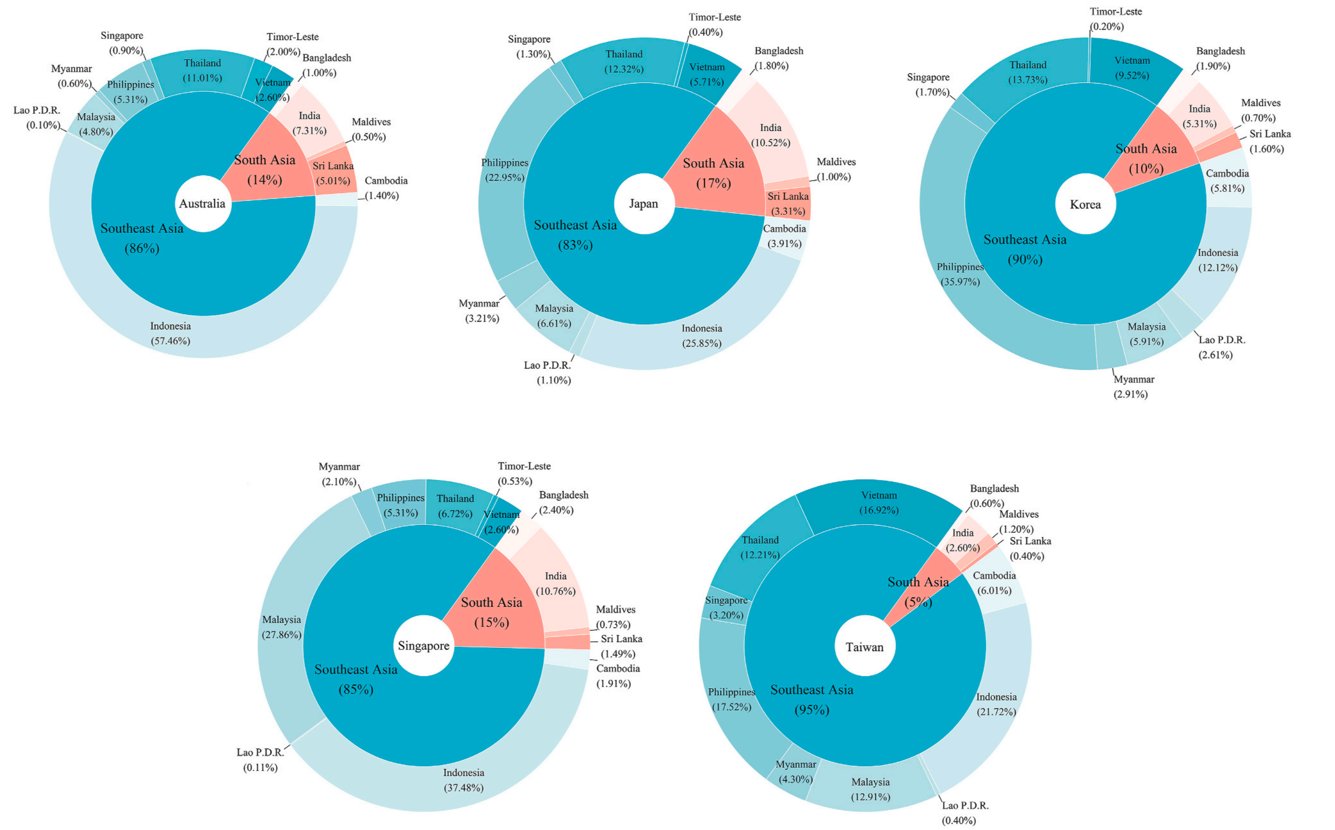


**Fig. 1.** Proportionate distribution of dengue cases in returning travelers to the WP5, who visited any of the ten Southeast Asian and four South Asian destination countries from 2010 to 2018.

**Table 1**
Characteristics of dengue cases in travelers returning to the WP5 from 2010 to 2018.

| Sentinel site | Number of reported dengue cases | Incidence per 100,000 travelers | Length of stay per travel (days) |
|---|---|---|---|
| Australia | 9665 | 40.7 | 15–16 |
| Japan | 1666 | 4.7 | 6.5 |
| Korea | 1473 | 3.2 | 7.5 |
| Singapore | 2482 | 1.7 (including who visited Malaysia) | 7.0 |
| | 1752 | 6.3(excluding who visited Malaysia) | |
| Taiwan | 2364 | 16.3 | 8.1 |

(Fig. 3). Using Malaysia as an example, the reported dengue incidence was 69.4 cases per 100,000 people in 2011. However, in 2015, it surged to 399.2 cases per 100,000 inhabitants, averaging over 200 cases annually per 100,000 people. Australia's travel-related dengue incidence when visiting Malaysia exhibited yearly fluctuations, peaking in 2015 and reaching a low in 2010. In contrast, India consistently reported fewer than 10 dengue cases per 100,000 individuals annually throughout most of the study period, except in 2017 (Fig. 3). Notably, India witnessed a gradual increase in its annual incidence from 2010 to 2017, with a sharp downturn in 2018. However, most sentinel-site countries did not mirror this pattern in their dengue rates per 100,000 travelers to India over the same timeframe. Specifically, for travelers returning from India to Taiwan, the annual dengue incidences per 100,000 population decreased from 2010 to 2014, further declined until 2016, and then increased in 2017.

When comparing the estimated dengue incidences among travelers from the WP5 who visited eight destinations in Southeast Asia and South Asia with the officially reported dengue incidences per 100,000 inhabitants in those nations, the estimated dengue incidence per 100,000 visitors to Malaysia showed the strongest correlation with the reported dengue incidence within the nation ($r = 0.66–0.92$) (Fig. 4). Indonesia follows closely, demonstrating a significant correlation ($r = 0.56–0.98$). In contrast, the correlation between estimated dengue incidence per 100,000 travelers and reported dengue incidence per 100,000 residents in India is relatively weak ($r = −0.54–0.76$). Correlation coefficients for dengue incidence among travelers and residents in other destinations are as follows: Cambodia ($r = 0.23–0.81$), Myanmar ($r = 0.51–0.91$), the Philippines ($r = −0.35–0.76$), Thailand ($r = 0.18–0.81$), and Vietnam ($r = 0.06–0.84$).

## 4. Discussion

This study initially investigated dengue infection cases among travelers returning to the WP5 from 14 tropical Asian countries, determining the relative proportion of infected individuals by destination. Subsequently, we estimated dengue incidence in returning travelers to eight popular Southeast and South Asian destination countries from 2010 to 2018. Using this time-series data, we assessed the correlation between dengue incidence in destination countries and in sentinel sites, to evaluate the effectiveness of surveillance in eight destination nations. Significant variations in estimated annual dengue incidences per 100,000 travelers were observed across the eight most popular destination countries from 2010 to 2018. On average, Malaysia had the lowest dengue incidence, followed by Thailand and Vietnam. Conversely, India and Myanmar exhibited the highest dengue incidence among the analyzed countries. However, temporal trends of annual dengue incidence estimated from traveler's data in sentinel sites to that of each destination country showed similar patterns. This suggests that dengue sentinel traveler surveillance is beneficial for gauging the dengue burden in specific destination countries.

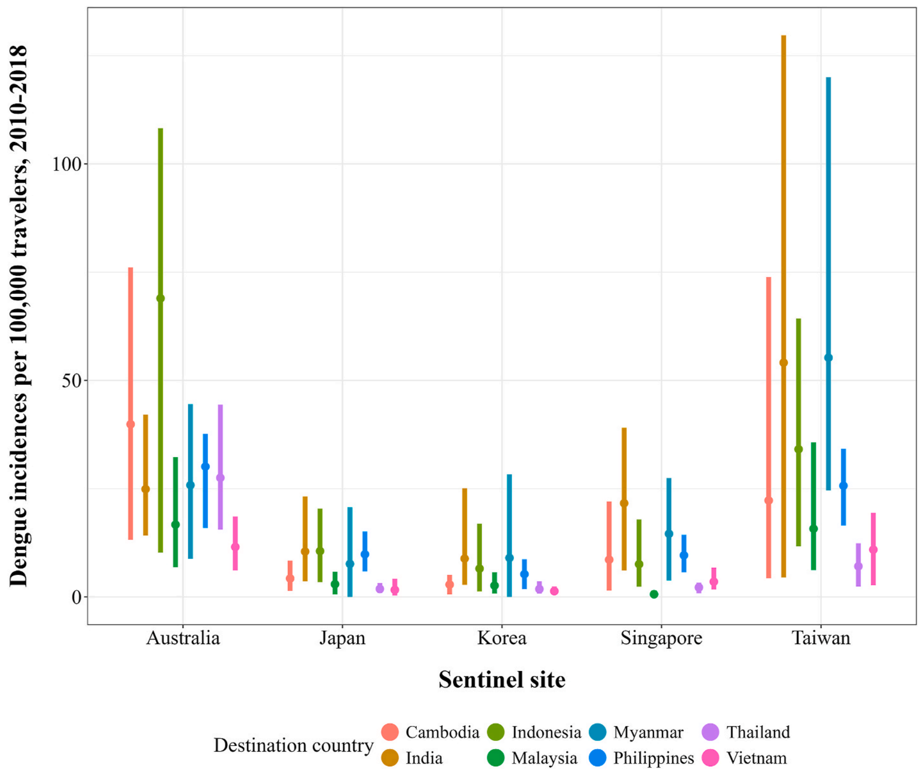


**Fig. 2.** Maximum, mean, and minimum values of annual dengue incidences per 100,000 travelers returning to the WP5, categorized by the eight destination countries in Southeast Asia and South Asia, spanning from 2010 to 2018.

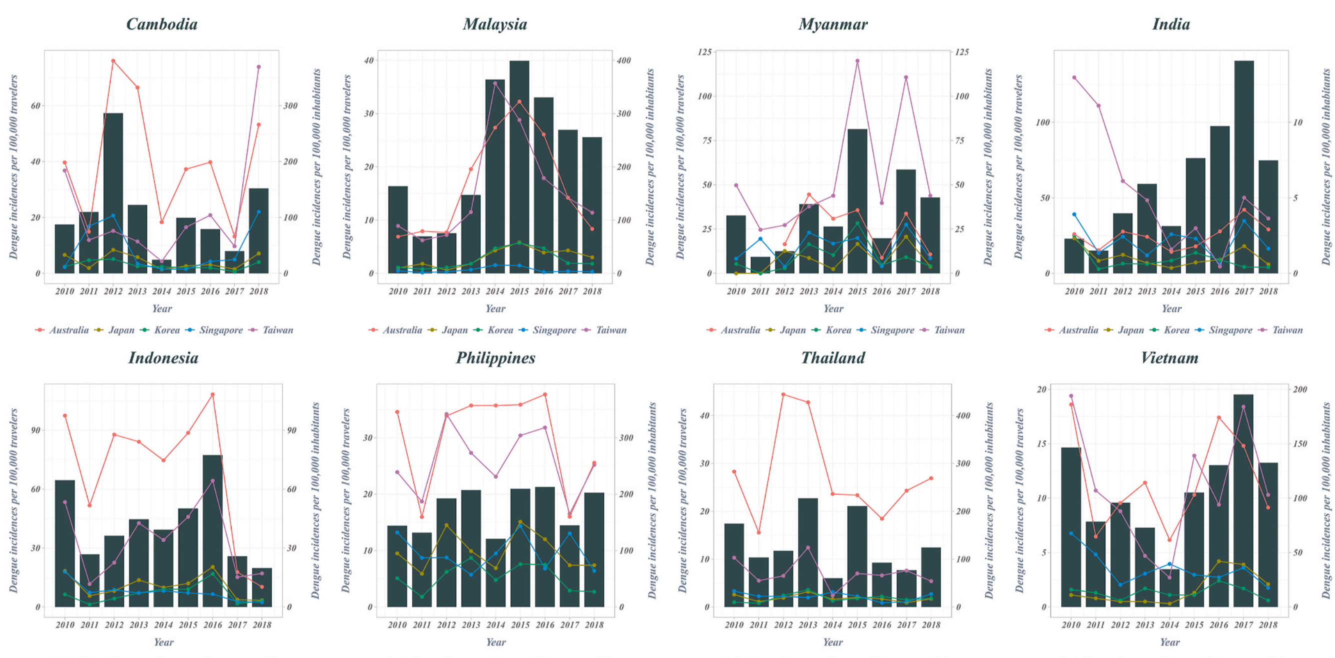


**Fig. 3.** Annual dengue incidences per 100,000 travelers returning to the WP5, and the annual dengue incidence per 100,000 inhabitants in each of the eight destination countries in Southeast Asia and South Asia from 2010 to 2018.

When comparing dengue incidence among residents and travelers returning to the WP5 the strongest correlation was observed in Malaysia and Indonesia (Fig. 4). This suggests robust national dengue surveillance systems are in place in these two countries, effectively capturing the overall temporal pattern of case occurrence within their regions. However, it is also important to be cautious when interpreting these correlations. While the strong correlation in dengue incidence between residents and travelers returning to the WP5 may indicate similar trends, it doesn't necessarily mean that the data effectively captures the total number of infected individuals in national surveillance. In Malaysia, all suspected or confirmed dengue cases are reported through an online system to local health authorities [12]. This existing passive surveillance

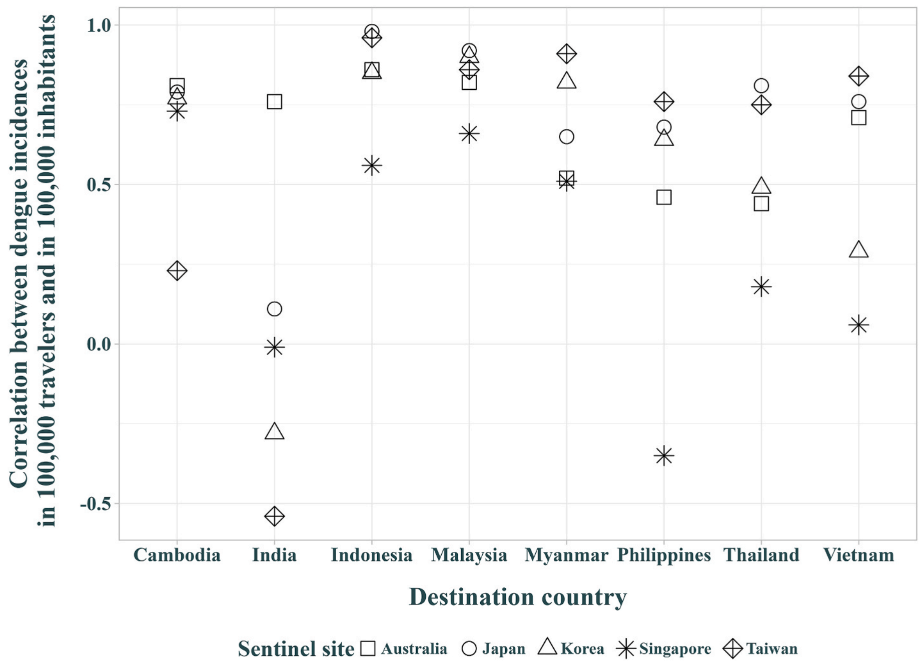


**Fig. 4.** Correlation between dengue incidences per 100,000 travelers returning to the WP5, and the annual dengue incidence per 100,000 inhabitants in each of the eight destination countries in Southeast Asia and South Asia from 2010 to 2018.

system in Malaysia is considered a potential early warning system for outbreaks, but it is crucial to acknowledge that despite these high standards, a gap may exist between the actual dengue burden and cases reported due to asymptomatic instances [13]. In Indonesia, with its vast geographical expanse, regulation by Ministry of Health requested hospitals to report any new dengue cases to district health offices within 24 h after confirmed diagnosis, with a vertical reporting system operating from the district to the national level for decades, despite issues like under-reporting [14]. Our findings align with a recent study indicating a linear time-series pattern in Google Trends data, statistically well correlated with official annual dengue reports [15].

Conversely, the correlation between the incidence of dengue among travelers from the WP5 and the annual dengue incidence in India is significantly lower compared to tropical Asian countries. This raises concerns about the representativeness and reliability of India's dengue surveillance system. In 2014, a study indicated that the actual number of dengue cases in India per year could be more than 200 times the officially reported figure [16]. Dengue surveillance in India operates through passive, sentinel, and hospital-based methods, known for their weaknesses, including data reliability, under-reporting, and fragmentary information [17]. Effective surveillance of communicable diseases in India faces challenges due to limitations in human resources and surveillance infrastructure, including diagnostic capacity [18]. The correlation between dengue incidence among travelers returning to Singapore and dengue incidence in various destination countries is notably low, unlike in the other four Western Pacific nations and territories. This discrepancy is attributed to the endemic dengue status of Singapore, coupled with short visits by many Singaporeans to neighboring Malaysia, making it challenging to accurately infer the origin of infection and the epidemic status of the destination country through traveler surveillance.

We consider this approach a novel and practical application of sentinel traveler surveillance, with travelers returning to these reliable "sentinels" after visiting dengue-endemic regions. The underlying assumption is that trends in dengue infection among travelers accurately mirror local dengue patterns seasonally and annually [19]. Our unique method pairs multiple sentinel sites with diverse destination countries, providing results valuable for regional or global analysis. Due to variations in disease statistics from routine notifiable disease surveillance in endemic countries, a direct country-to-country comparison of notified dengue incidence is unfeasible. This discrepancy arises from differences in case definitions, inclusion of probable cases without laboratory confirmation, variations in awareness of dengue symptoms, access to health services, and diagnostic availability. In contrast, dengue surveillance in the WP5 offers advantages and similarities. Here, dengue cases are strictly identified through laboratory confirmation, and there is relatively equal access to health services with a robust national infectious disease surveillance system [20]. Consequently, we could directly compare annual occurrence patterns of dengue between destination countries, bypassing inherent differences in their respective surveillance systems using sentinel traveler incidences as reference values. Moreover, our approach aids in assessing the true burden of the disease [21] for destination countries heavily reliant on passive surveillance based on clinical diagnosis in their national dengue surveillance.

Several considerations are pertinent when interpreting these study results. Not all 14 tropical Asian countries with dengue cases were analyzed, owing to disbursement distributions across the WP5. Some sentinel sites had a more significant impact due to unique sociodemographic and geographic characteristics in each country, along with varying accessibility levels to destination countries. For instance, the northwestern region of Australia, being in proximity to Indonesia, attracts over 400,000 annual visits [22]. This aligns with our data, revealing that more than half of confirmed dengue cases among travelers to the 14 tropical and subtropical Asian destination countries originate from Indonesia. Also, higher incidences of dengue were observed among travelers returning to Australia compared to counterparts from four other countries (Table 1) returning from popular destinations. This is attributable to Australians frequently visiting Indonesia, a country with a notably elevated dengue rate (Fig. 2). The risk of dengue infection per 100,000 visitors also rises with prolonged stays in countries with high dengue incidence [23]. Notably, there are disparities in the length of stay between Asian and European or Oceania travelers (Table 1). Australians typically travel for a median duration of 15–16 days, mirroring European patterns. The average outbound travel duration for the other four countries is around 7 days, aligning with official statistics for Korean, Japanese, Taiwanese, and Singaporean travelers.

The incidence of dengue among travelers from Taiwan and Singapore (excluding who visited Malaysia) to eight tropical Asian countries was two to five times higher than that among travelers from Korea and Japan. Despite similar trip durations, we believe that this disparity is attributed to the robust national surveillance systems in Taiwan and Singapore rather than other travel-related factors, such as the season of visit and the environment. Also, the distribution of destination countries does not significantly vary [24,25]. Compared to Korea and Japan, where autochthonous dengue cases are rare, Taiwanese and Singaporean travelers with dengue-like symptoms are more likely to be diagnosed, although factors beyond departure countries can influence dengue. In Taiwan, a non-endemic region, the weighted overall seroprevalence of anti-DENV IgG was 3·4 % in samples collected in 2010 [26]. Post the 2003 SARS outbreak, Taiwan implemented airport fever-screening to identify potential infections in returning travelers with fever [8]. Additional tests followed for those with temperatures above 38 °C, arriving from dengue-prone areas, likely contributing to increased dengue cases among travelers from tropical Asian countries. With over 1000 cases reported annually in the 2010s and major outbreaks in 2014 and 2015 [27], clinicians' awareness of dengue may have risen. Singapore, a dengue-endemic country, has a 50 % age-weighted dengue-specific IgG prevalence, with active screening for dengue through rapid diagnostic tests for acute febrile illness [28] incidence among travelers.

When establishing retrospective surveillance via sentinel sites, we initially assumed uniform exposure to dengue-infected mosquitoes across all destination countries during a single overseas trip. However, this assumption was challenged by the returning travelers to Japan. Despite Thailand being the most frequented tropical Asian destination for Japanese tourists, hosting more visitors than the Philippines and Indonesia during the study period, our analysis revealed that only 12·3 % of imported dengue cases in Japan originated from Thailand. This is significantly lower than cases from Indonesia (25·8 %) and the Philippines (22·9 %). This suggests that the actual risk of contracting dengue in Thailand may be lower compared to the other two countries. Similarly, among tropical Asian countries, Malaysia ranked highest in foreign visits, followed by Indonesia and Thailand. While the average number of Asian travelers to Malaysia, Indonesia, Thailand, and India varies annually, the proportion of travelers infected with dengue during overseas travel was notably highest in Indonesia (37·5 %), followed by Malaysia (27·9 %), India (10·8 %), and Thailand (6·7 %). This underscores the non-uniform nature of the risk of contracting dengue per trip across countries. The risk of dengue susceptibility may vary across countries due to differences in prevalent dengue serotypes, the level of immunity to those serotypes in the population, the effectiveness of mosquito control measures, health infrastructure, and the behaviors of tourists in different destinations.

Previous research predominantly focused on determining actual dengue cases rather than evaluating each country's dengue surveillance system [29]. While beneficial for policymakers in endemic countries, these methods are expensive and intricate. Notably, past attempts to gauge the true scale of dengue relied on specialized techniques, such as an "expansion factor" derived from active dengue surveillance in cohorts [29]. Hence, we propose establishing a more responsive and systematically structured dengue surveillance system, especially in the Western Pacific region. This system should leverage traveler surveillance data to accurately reflect fluctuations in dengue incidence in tropical Asian countries. The necessity for such a system arises from challenges in estimating and comparing dengue incidence across endemic countries, considering variations in case definitions solely based on each country's notification data. Given these inherent challenges due to health system disparities and diverse surveillance systems, we strongly recommend the WHO Western Pacific Regional Office incorporate traveler surveillance data on dengue from available countries into the Dengue Situation Update in the Western Pacific Region [20,30]. These data can serve as basis for sentinel-site surveillance which could provide useful epidemiological information in destination countries where dengue is endemic. However, basic data research needs to be prioritized before these systemic improvements can begin to take hold at the policy level. To ensure that the results of this study can be applied to other Southeast Asian and Western Pacific countries, it is important to thoroughly assess the effectiveness and inclusiveness of dengue surveillance systems in those countries beforehand. Additionally, reliable data on the size of the visiting tourist population should be accessible.

This study has some limitations. First, the clinical manifestations of dengue infection can vary widely, ranging from asymptomatic or mild to severe. Not all travelers become ill or seek medical attention upon returning home, even if infected. Consequently, the estimated incidences may not truly represent the actual occurrences but might be underestimated. Second, travelers typically visit popular tourist attractions or major cities rather than exploring the entire destination country. This tendency could restrict reported dengue cases among travelers, reflecting only the status of dengue occurrences in the specific places they frequent. Similarly, when a traveler visits multiple countries, it remains unclear which destination serves as the source of infection. During epidemiological investigations upon the traveler's return, dengue surveillance data from sentinel site countries and territories only permit the identification of a single destination country. This situation could potentially lead to misclassification. Also, we assume that all returning travelers to a given country are nationals of that country, though this may not always hold true. Lastly, the effectiveness of dengue surveillance systems in detecting infections among travelers differed across the WP5. Although we did not consider these variations in our analysis, we maintained consistency in case definitions, relying on laboratory-confirmed dengue cases. This approach aimed to reduce heterogeneity in the analyzed dengue cases.

We would like to propose the following measures to complement these limitations. Dengue cases are often underreported, particularly among travelers returning from extended trips abroad. Currently, returning travelers may not report dengue cases if they have already been treated and cured before returning. To improve reporting, incentives or regulatory measures should be introduced. Changes in travel patterns can be identified by surveying travelers or using roaming data from their mobile phones. When a traveler visits multiple countries and develops dengue fever upon returning, the country of infection should be determined through detailed epidemiological investigation. If this method is limited, a classification logic can be created to classify the area of longest stay as the presumed infection area, reducing the risk of misclassification.

## 5. Conclusion

Analyzing dengue sentinel surveillance data from returning travelers to the WP5, we estimated proxy-dengue incidences for eight favored tropical and subtropical Asian destinations spanning 2010 to 2018. We gauged the efficacy of dengue surveillance systems in destination countries by comparing them with annual incidences derived from national dengue surveillance records. Malaysia and Indonesia exhibit robust dengue surveillance, with reported annual incidences aligning closely with trends among travelers to the sentinel-sites. In contrast, India's dengue surveillance appears comparatively less effective. Estimated annual dengue incidences from travelers returning to sentinel site countries with well-established disease surveillance offer a reliable measure for evaluating dengue surveillance in nations with less robust systems but endemic dengue.

## CRediT authorship contribution statement

**Jong-Hun Kim:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Ah-Young Lim:** Formal analysis, Data curation. **Sung Hye Kim:** Writing – review & editing, Validation, Methodology.

## Informed consent statement

Not applicable for this study because this study is a secondary analysis of anonymized data.

## Institutional review board statement

Ethical approval was obtained from the Institutional Review Board of Sungkyunkwan University (IRB File No. 2021-04-010).

## Data sharing statement

The dataset collected in this study is available in the public domain of each responsible national authority.

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## 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.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tmaid.2025.102802.

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