Assessing the Impact of Temperature on the Duration of COVID-19 Transmission in Terengganu, Malaysia: Implications for Public Health Strategies

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ABSTRACT

Introduction: The SARS-CoV-2 virus, responsible for the global COVID-19 pandemic and its associated high morbidity and mortality, continues to be a significant public health concern. This study investigates the influence of temperature variables on COVID-19 transmission in Terengganu, Malaysia, which, despite having experienced a comparatively lower number of cases, presents a unique environment for understanding how temperature factors may play a critical role in virus transmission dynamics.

Materials and Methods: We conducted a descriptive analysis to assess the spatial distribution of COVID-19 cases in our study area. To explore the relationship between temperature variables and COVID-19 transmission, we employed Pearson correlation analysis, examining the correlations between daily average, minimum, and maximum temperature data and the temporal distribution of COVID-19 cases as reported by the Ministry of Health, Malaysia. This approach allowed us to comprehensively investigate the impact of weather on the transmission dynamics of COVID-19.

Results: Our findings reveal a noteworthy correlation ($p<0.05$) between average and maximum temperatures and COVID-19 transmission, highlighting the influence of weather on disease dynamics. Notably, exceptions were observed in the Hulu Terengganu district, where fewer than 10 cases occurred in each sub-district throughout the study period, warranting special consideration.

Conclusion: In summary, our study highlights the significance of temperature in shaping COVID-19 transmission. This stresses the importance of including weather variables in pandemic strategies. We also suggest comparing various cities to broaden our understanding of how weather affects disease spread, aiding future public health efforts.

KEYWORDS:
COVID-19, weather, temperature, Terengganu, Malaysia

INTRODUCTION

The emergence of coronavirus disease in 2019 (COVID-19) has triggered a global health emergency. The disease is transmitted primarily by droplets in the breath when an infected person coughs, sneezes, or talks; however, it can also be transmitted through contact with contaminated surfaces.[1] Symptoms of COVID-19 can range from mild to severe and include fever, cough, fatigue, body aches, loss of taste or smell, and shortness of breath. The disease can lead to pneumonia, acute respiratory distress syndrome (ARDS), and even death in severe cases. The incubation period for COVID-19 is usually 2-14 days after exposure, during which asymptomatic but contagious persons may be present.

Environmental factors such as temperature, humidity, and wind speed have been shown to play a role in the transmission and survival of SARS-CoV-2. Studies suggest that the virus is more stable at low temperatures and low relative humidity, and that higher wind speeds may facilitate the spread of the virus over longer distances.[2-4] Understanding these factors may help in the development of COVID-19 containment strategies. Epidemiological modelling of infectious diseases such as COVID-19 often requires population scaling to account for differences in disease transmission patterns across populations. This is because different population variables, such as population density and social interactions, can influence the mechanisms that determine the spread and duration of epidemics. Epidemic transition models with population scaling are advisable for a better understanding of infectious disease transmission and management.[5]

Previous studies on the impact of meteorological factors on COVID-19 transmission up to September 2021 suggested the possibility of some seasonality, with warmer and more humid conditions potentially reducing transmission rates. While research indicated that higher temperatures and humidity might reduce the stability of the virus, inconsistencies in data, global variations, and the complex interplay of other factors made it difficult to establish a clear and universal relationship between meteorological factors and COVID-19 transmission. Furthermore, research was ongoing, and the understanding of this relationship might have evolved since

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that time, particularly in the context of specific regions like Malaysia.

Therefore, the objective of this study is to examine the correlation between temperature and COVID-19 transmission in Terengganu, Malaysia, a region with a relatively low number of confirmed virus cases. This research aims to enhance our comprehension of the determinants of COVID-19 transmission and potentially inform the development of effective public health measures and interventions to mitigate the virus's spread.

MATERIALS AND METHODS

Study Site and Population

The study was conducted in Terengganu, a state on the east coast of Peninsular Malaysia between 103.1324° E and 5.3117° N. The state is divided into eight main administrative districts, including Kemaman, Dungun, Marang, Kuala Terengganu, Hulu Terengganu, Setiu, Kuala Nerus, and Besut. The Kuala Terengganu district is the most populous and serves as the administrative centre of the city. Terengganu has a total area of 13,035 km^2 and a population of 1.125 million (as of 2013) (Fig. 1). The lower number of cases in Terengganu provides an opportunity to investigate the interplay between temperature and virus transmission in a less-affected region. By studying this context, we aim to offer valuable insights into potential patterns and implications that may have relevance in both tropical and global contexts. The strategic choice of Terengganu allows us to explore the impact of climatic conditions on COVID-19 transmission, contributing to the broader understanding of the factors influencing the spread of the virus in diverse environmental settings.

Study Design

In this integrated epidemiological study, we aimed to investigate the impact of weather variability on the distribution of COVID-19 cases in Terengganu, Malaysia. We conducted a cross-sectional study in 2021, utilizing data from the Ministry of Health of Malaysia (MOH) and the Malaysian Meteorological Department (MMD). The data sources included the distribution of COVID-19 cases and district-specific meteorological data, specifically temperature. We collected COVID-19 case data from eight major administrative districts in Terengganu, spanning 52 epidemiological weeks over one year (2021). Data collection commenced on August 1, 2020, and concluded on July 31, 2021, covering a full calendar year. Meteorological data on average, maximum, and minimum temperatures were sourced from official applications provided by the Malaysian Meteorological Department, ensuring data accuracy and quality for the study.

Data Collection and Management

The data collection and management for this study were conducted meticulously to ensure accuracy and reliability. The primary sources included the Ministry of Health of Malaysia (MOH) for COVID-19 case data and the Malaysian Meteorological Department (MMD) for meteorological data, specifically temperature. Data collection spanned from December 15, 2020, to March 23, 2021, capturing a significant period of COVID-19 transmission. Subdistricts with less than 10 confirmed cases during the study period and those with limited cases before or after the peak were excluded to avoid data sparsity. Descriptive analysis involved normalizing COVID-19 case data and calculating a 7-day moving average (Fig 2). Daily temperature data were collected from accessible weather stations in five Terengganu districts, with data backed by the MMD for accuracy. This rigorous data collection and management approach aimed to deliver reliable and valid results, essential for informing public health strategies and understanding temperature's impact on COVID-19 transmission in Terengganu, Malaysia.

This study aims to investigate the influence of temperature on the duration of COVID-19 transmission in Terengganu, Malaysia, focusing on the "spreading phase" and "decay phase." The "spreading phase" is defined as the period from the onset of the outbreak until the daily or weekly new case counts reach a peak and begin to stabilize or decrease, signifying the initial stage of the outbreak when the virus is actively transmitted. The "decay phase" follows the peak, representing the time when new cases consistently decrease until reaching a stable or low level, indicating a declining transmission phase. These operational definitions will be used to assess how temperature affects the duration of each phase, with implications for informing public health strategies.

Data Analysis

The data analysis in this study was structured to investigate the relationship between weather variables and COVID-19 transmission, with a specific focus on Transmission Duration. Transmission Duration was clearly defined as the period from the onset of the COVID-19 outbreak in Terengganu, marked by the first confirmed case, to the beginning of the "decay phase" characterized by consistently decreasing daily or weekly case counts. The analysis commenced with the collection of daily temperature data from five local weather stations in Terengganu for the year 2021. In this study, the hierarchical clustering technique was employed, resulting in the identification of two distinct clusters or groupings. The initial cluster, designated as the "red group," encompasses districts exhibiting a higher temperature association compared to the second cluster. This clustering method serves as a valuable tool for exploratory analysis and can facilitate subsequent in-depth investigations. Then, a Pearson correlation analysis was then conducted to examine the linear relationships between weather variables and COVID-19 cases. Subsequently, cross-correlation analysis was employed for each district in Terengganu, dividing the analysis into eight distinct sections, one for each district, to facilitate a detailed understanding. This approach allowed for the determination of the percentage of correlation between COVID-19 cases and temperature variables, providing insights into the impact of weather on COVID-19 transmission in Terengganu. Importantly, a significance level (p-value) of 0.05 was applied to ensure the statistical significance of the results, enhancing the credibility of the findings and their relevance to public health strategies.

Ethics Approval and Infprmed Consent

No ethical issue required for this research

Table I: Starting and terminating dates of the spread and decay stages of the COVID-19 pandemic and the date (year 2020 and 2021) when the highest daily peak value of confirmed cases was reported. Time parameters extracted from the definition are TSS (start of spread), TSE (end of spread), TDS (start of decay), TDE (end of decay), DS (spread duration), and DD (decay duration)

Districts	TSS	TSE	Daily Peak	TDS	TDE	DS	DD
Bukit Kenak	2-Jan	8-Feb	12-Feb	16-Feb	20-Mar	37	33
Jabi	11-Jan	7-Feb	2-Feb	17-Feb	1-Mar	27	13
Kg Raja	8-Jan	31-Jan	5-Feb	10-Feb	20-Mar	23	10
Kerandang	6-Jan	17-Jan	22-Jan	27-Jan	17-Feb	11	22
Kbg. Bemban	22-Jan	11-Feb	12-Feb	17-Feb	22-Mar	16	34
Lubuk Kawah	8-Jan	31-Jan	5-Feb	10-Feb	15-Mar	23	34
Pelagat	7-Jan	21-Jan	22-Jan	27-Jan	17-Mar	10	48
Kuala Besut	21-Jan	8-Feb	13-Feb	18-Feb	17-Mar	18	28
Jerangau	8-Jan	11-Jan	16-Jan	21-Jan	13-Feb	3	23
Rasau	6-Jan	9-Jan	14-Jan	19-Jan	13-Feb	3	25
Sura	8-Jan	23-Jan	28-Jan	2-Feb	24-Feb	15	22
Paka	19-Jan	7-Feb	12-Feb	17-Feb	22-Feb	19	5
Kerteh	11-Jan	16-Jan	21-Jan	26-Jan	1-Feb	5	6
Chukai	8-Jan	24-Jan	29-Jan	3-Feb	13-Feb	16	10
Bukit Payong	18-Jan	19-Jan	24-Jan	29-Jan	8-Feb	1	10
Bandar	7-Jan	25-Jan	30-Jan	4-Feb	26-Feb	18	22
Chabang Tiga	5-Jan	7-Jan	12-Jan	17-Jan	31-Jan	2	14
Chendering	11-Jan	17-Jan	22-Jan	27-Jan	13-Feb	6	17
Manir	8-Jan	17-Jan	22-Jan	27-Jan	17-Mar	9	49
Serada	8-Jan	10-Jan	15-Jan	20-Jan	15-Feb	2	26
Kubang Parit	22-Feb	4-Mar	9-Mar	14-Mar	20-Mar	10	6
Kepong	21-Jan	26-Jan	31-Jan	5-Feb	7-Feb	5	2

Table II: Correlation between the spread (DS) and decay durations (DD) of COVID-19 transmission with daily average, maximum, and minimum temperature

	DS			DD		
District	Avg	Max	Min	Avg	Max	Min
Kemaman	0.050	0.190	-0.103	0.305	0.382	0.305
K.Tgganu	-0.471*	-0.443*	-0.216	0.491*	0.801*	-0.207

RESULTS

Table I lists the start and end dates of the spread and decay phases (using a 7-day moving average) and the date of the highest number of confirmed cases observed daily in each county and subcounty.

Figure 3 is a graphical representation of the time series of confirmed new positive cases during the spread and relapse phases of the pandemic. Fig. 3a shows that the number of normalized confirmed cases increased in most districts, with some districts having multiple maxima. This indicates that the pandemic did not spread evenly across all districts and that some districts experienced multiple waves of infection. Fig. 3b shows the decline of the pandemic, with the number of normalized confirmed cases decreasing over time in most districts. Similar to Fig. 3a, multiple maxima were observed in certain districts, suggesting that the pandemic decline was not uniform across all districts. For policymakers and public health officials, these findings are critical for targeting interventions to control the spread of the pandemic in specific districts and regions.

In this case, the hierarchical clustering technique yielded two distinct clusters or groupings. The first group, referred to as the "red group," consists of districts with a higher temperature association than the second group. Depending on the context of the analysis, the second group may or may not be identified by a particular colour. The red group of districts is easily distinguished from the other groups, as shown in Fig. 4. This clustering method can be used for exploratory purposes or to facilitate further analysis, and interpretation of the clustering result should be based on the specific context and objectives of the analysis.

Table II show that there is a statistically significant, moderately positive correlation between the duration of degradation and the average and maximum temperatures in the Kuala Terengganu district. This was determined using Pearson's correlation coefficient, which measures the linear relationship between two variables. The p-value of both the average and maximum correlation coefficient with the expiration time is below the 5% significance level, which means that the correlation coefficients are significantly different from zero. Therefore, the null hypothesis, which states that there is no linear correlation between these variables, can be refuted.

The correlation coefficients (r) between the decay time and the average and maximum temperatures are 0.49 and 0.80, respectively. These values indicate that there is a moderately positive linear relationship between these variables. This indicates that the decomposition time tends to increase with increasing temperature. In addition, the results show a statistically significant, moderately positive correlation between the duration of dispersal and the average and maximum temperatures in Kuala Terengganu. For both

Fig. 1: The geographical representation of the area of interest for this study which is Terengganu

average and maximum temperatures, the P-values for dispersion duration are less than 0.05, which is at the significance level. The observed correlation coefficients between dispersion duration and average and maximum temperatures are -0.471 and -0.443, respectively. These values indicate that these variables have a moderately negative linear relationship. This means that the dispersion duration tends to decrease as the temperature increases.

DISCUSSION

Environmental health researchers have been interested in the effects of temperature on human health and disease transmission for decades. The current pandemic COVID-19 has brought this issue to the forefront of public attention, and the effects of temperature on disease transmission have been discussed extensively in many countries, including Japan. Japan is an optimal location for studying the environmental factors that may affect the spread of COVID-19 [6,7] because it has a high-quality health care system, social measures, and consistent data collection. However, one of the difficulties in analysing COVID-19 data there is the limited availability of data due to various policies in Japan and problems with data consistency, reliability, and uniformity.

In this study, the duration of the propagation and recovery phases of COVID-19 and the effects of temperature on these phases were investigated to address this problem. The results provide valuable insights into the effects of temperature on

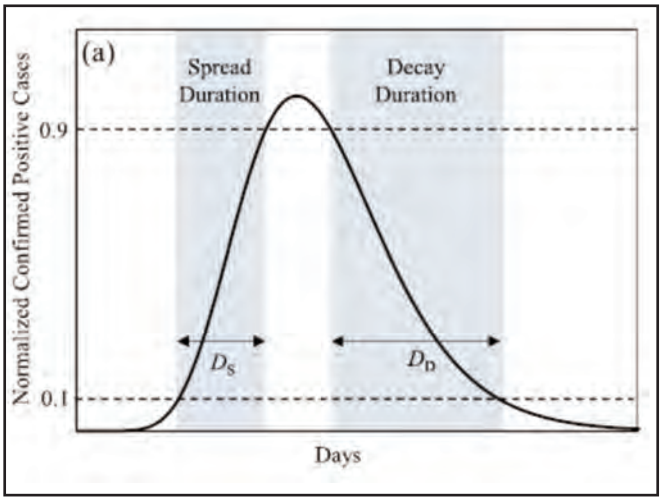

Fig. 2: Proposed definition of the spread and decay durations along the curve of the COVID-19 pandemic, which has been applied to the 7-day moving average of original data. Time parameters extracted from the definition are TSS (start of spread), TSE (end of spread), TDS (start of decay), TDE (end of decay), DS (spread duration), and DD (decay duration)

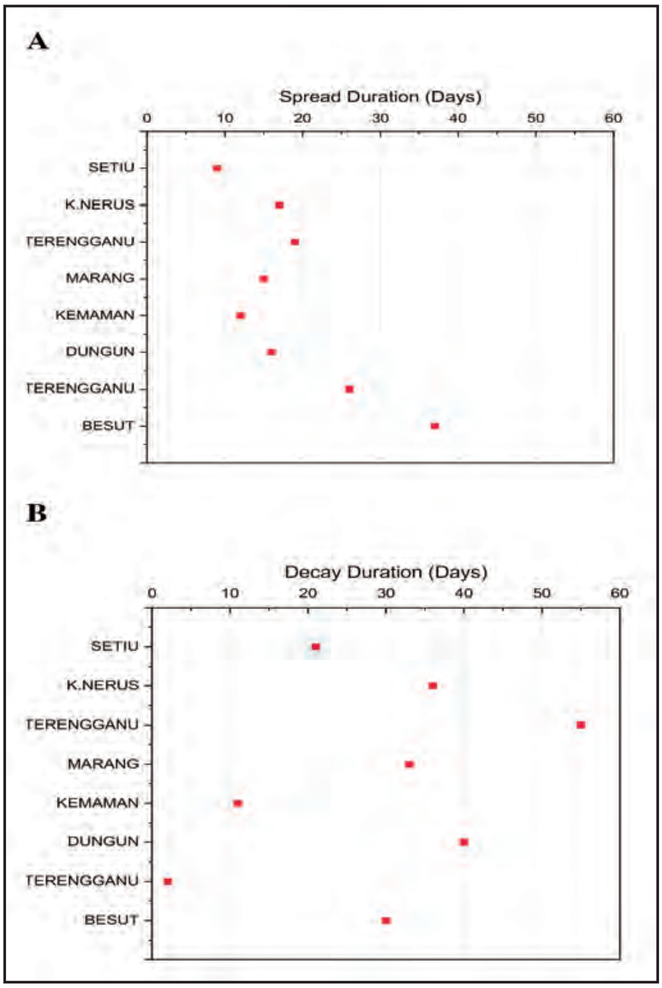

Fig. 3: (a) Spread and (b) decay durations (in days) of analyzed districts in Terengganu

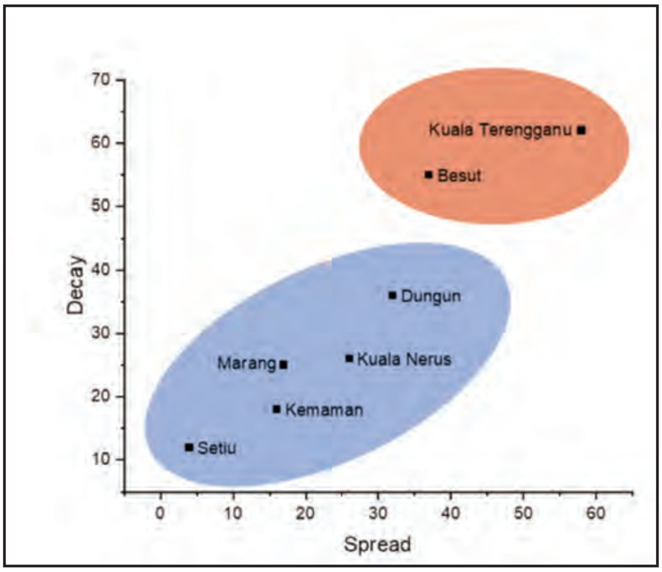

Fig. 4: Relationship between the durations of spread and decay (in days). The red ellipse highlights districts with relatively high temperature, while the blue ellipse highlights those with relatively low temperature

the transmission phase of a pandemic and can be used to formulate plans and measures to control the spread of disease.[8] It is important to note that the results of this study may not be directly applicable to all situations, as environmental factors and social responses to disease outbreaks can vary widely by region and country. However, the results contribute to our understanding of how temperature affects the spread of COVID-19 and can serve as a basis for decision making and planning in similar situations. This study highlights the importance of considering environmental factors such as temperature when assessing the risk of pandemic transmission.

This study compares the COVID-19 spread and decay duration of 7 districts in Terengganu where more than 10 cases were confirmed during the studied wave. The Hulu Terengganu district was excluded from the analysis because all of its sub-districts had fewer than 10 cases throughout the study period. The study used the range of 10-90% of normalized confirmed cases to establish the metrics for both time periods. Normalization was performed to avoid potential differences in the absolute number of reported cases between districts due to differences in regulations. One of the challenges faced by the study was the relatively low number of COVID-19 cases in Malaysia compared to other countries. The number of cases in Malaysia was one to two orders of magnitude lower than most European countries.[9] This made it difficult to collect enough data to perform a robust analysis. However, because the study focused on districts with higher numbers of cases, it was able to provide useful insights into the prevalence and decline of COVID-19 in the Terengganu region.

The results of this study show that the number of confirmed COVID-19 cases generally follows a bell-shaped or lognormal curve, with an increase followed by a decrease.[7] However, in Besut and Kuala Terengganu districts, several peaks were observed in both the spread and decay phases. Hierarchical cluster analysis revealed that these two districts belonged to the same cluster as they had relatively high daily temperatures (26.3°C-28.1°C) during the propagation phase. Temperature data were obtained from weather stations in Kuala Terengganu and Felda Belara. Both districts recorded relatively long duration of propagation days, 58 and 37 days, respectively. In addition, these two districts recorded the highest number of days for rot duration at 62 and 55 days, respectively.

However, the fact that temperature was considered high does not fully explain the longer duration of transmission in these two districts. Other factors such as the increase in the number of travellers returning from other countries/regions, the lack of social distance, and attendance at large gatherings without following standard operating procedures (SOPs) may have contributed to the longer transmission duration.15-18 It is worth noting that the study excluded counties with minor spikes to ensure robustness of conclusions.

It is important to recognize that comparing the results of this study with those of other countries is difficult because of differences in the measurement of data with different SOPs, testing rates, validation techniques, and other factors that may introduce bias. In addition, closure restrictions and public responses are also important factors affecting the accuracy of the data from COVID -19.

The collection of various data sets can provide a basis for developing a predictive model for the future outbreak of COVID-19, a critical aspect of public health planning. The collected data will be analysed using a causal relationship focusing on epidemiological patterns of COVID-19 transmission and meteorological trends, and statistical models will be developed to determine the relationship between temperature and COVID-19 cases. These data will help stakeholders such as investors, public health epidemiologists, and health professionals understand the prevalence of COVID-19 transmission in their respective areas and make informed decisions. Due to the unique meteorological conditions in Terengganu, the results of this study may also assist policy makers in developing effective and targeted strategies to prevent the spread of COVID-19.

In this study, certain limitations should be acknowledged, primarily stemming from the decision not to incorporate temporal lags into our analysis. The dataset utilized exhibited specific characteristics, including limited temporal granularity and insufficient historical data, posing challenges to the effective integration of temporal lags. Moreover, the nature of the relationship between temperature and COVID-19 in the study area may not prominently feature delayed effects; instead, it might be more immediate in nature. This characteristic of the relationship influenced our decision to adopt a non-lagged approach. The constraints imposed by resource and time considerations also played a pivotal role in shaping our methodology. Conducting a more extensive analysis involving temporal lags would have necessitated additional data processing, computational resources, and time commitments, which were beyond the scope of this study. Despite these limitations, we believe that our chosen approach still yields meaningful insights into the relationship between temperature and COVID-19 transmission within the specific constraints of our study. We appreciate the reviewer's suggestion, and while acknowledging these limitations, we remain confident that our analysis, as presented, contributes valuable perspectives to the field.

CONCLUSION

In summary, this study provides insights into the correlation between temperature and stages of spread and decay of COVID-19 in 7 districts of Terengganu. Despite the limited number of cases reported, the uniformity of the data supports the conclusion that temperature can influence the duration of transmission. The results highlight the significant impact of temperature on COVID-19 transmission in Terengganu during the wave of infection studied. However, it should be noted that Hulu Terengganu district was excluded from the analysis because there were not enough cases, and there may be some exceptions. Therefore, when formulating protective strategies for a potential pandemic, including the next wave of COVID-19, it is critical to consider factors such as comparing multiple cities and district-specific exceptions.

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CONFLICT OF INTEREST

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

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