

Biological and ecological determinants of Hand Foot and Mouth Disease (HFMD) in Coastal District of Northeastern Peninsular Malaysia: A 5-Year retrospective study

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ABSTRACT

Hand, foot, and mouth disease (HFMD) is a prevalent viral communicable disease in Malaysia, known for its self-limiting nature but also for causing numerous outbreaks and fatalities, especially among young children. This study investigated the incidence, geographic distribution, temporal patterns, and determinants of HFMD in the Bachok District of Kelantan from 2018 to 2022. Using a cross-sectional analysis, data from the Communicable Disease Control Information System were examined, focusing on independent determinants and notification statuses. Analysis of 1351 HFMD's notifications revealed that predominantly involved men (56.7%) and were mainly managed in outpatient settings, with primary healthcare facilities being the most common treatment locations. The incidence of HFMD in the Bachok District peaked in 2022, displaying fluctuating trends over the years, with the Tawang sub-district consistently reporting the highest number of cases. Multiple logistic regression analysis indicated higher odds of HFMD among individuals attending primary healthcare or private practitioners, daycare attendees, cases occurring during the Southwest Monsoon season, and those before the implementation of the Movement Control Order, highlighting key determinants of HFMD. Thus, it is recommended that public health strategies focus on primary healthcare settings and involve daycare facilities, particularly during the Southwest Monsoon season. These health promotion strategies should be targeted and prioritised, especially during times of limited human and financial resources, to effectively manage and prevent HFMD.

Key words:

HFMD, determinants, Malaysia, young children, Monsoon

Citation:

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INTRODUCTION

Hand, foot, and mouth disease (HFMD) is a prevalent communicable disease in East and Southeast Asia, especially in Malaysia, where the first outbreak was recorded in 1997. Since then, Malaysia has been considered endemic for HFMD. The disease primarily affects children, although adults can also be infected.^{1,2} Transmission of HFMD occurs through direct contact or the fecal-oral route, with most cases caused by the coxsackie virus A16 (CA16). This virus generally causes a mild, self-limiting infection. However, the more severe cases of HFMD are occasionally caused by enterovirus 71 (EV71), a small, non-enveloped virus with positive-strand RNA.^{3,4} Symptoms of HFMD include the rapid development of ulcers and blisters in the oral cavity and vesicular lesions on the hands and feet. Severe complications can include meningitis, encephalitis, and neurogenic pulmonary edema.⁵

Multiple outbreaks of HFMD caused by EV71 have been reported primarily in Sarawak, East Malaysia, and Peninsular Malaysia, affecting thousands of children and resulting in 48 deaths.^{4,6} The determinants influencing HFMD in children are complex and include biological, ecological, clinical, and behavioural factors.^{7,8} Biological determinants substantially affect the progression of infectious diseases, which are influenced by the immune response, hormonal variations, and chromosomal predispositions. These factors indirectly affect disease susceptibility through variables, such as age and sex, affecting infection rates over an individual's lifetime.⁹ Ecological determinants refer to environmental factors that affect health and disease patterns in populations, including HFMD. These determinants include diverse external conditions, such as weather and

seasonality, and contexts in which people live, work, and interact, such as educational institutions.¹⁰ The incorporation of climate-specific variables into health promotion initiatives targeting HFMD cannot adequately address the negative effects on human health.¹¹ Although numerous studies, at least 51, have reported an association of climate variables with increased HFMD incidence, practical applications of these findings have been limited due to inconsistent and varying impacts of meteorological factors. Even in regions with similar climates, the effects on HFMD transmission and prevalence can differ substantially.^{11,12} Thus, a comprehensive analysis that extends beyond climate factors is crucial for developing effective health promotion strategies for preventing HFMD.^{4,12}

Due to the limited availability of specific antiviral medications and treatment options for HFMD, the focus of intervention has shifted towards vaccine development as a preventative strategy. Although an EV71 vaccine has been developed and recently introduced in China, its use is currently restricted to the Chinese population. This leaves other countries, including Malaysia, dependent on symptomatic treatments.¹³ Thus, challenges continue in effectively managing and curbing the spread of HFMD.

Despite numerous studies highlighting the effect of climate variables on the incidence of HFMD, there is limited research that integrates biological and ecological factors, particularly in the context of a coastal district. Current studies often lack detailed insights into the temporal and spatial patterns of HFMD at the district level, especially in areas with distinct monsoon seasons and varying healthcare infrastructures. This study addresses these gaps by providing a comprehensive analysis of the prevalence,

geographic distribution, temporal patterns, and determinants of HFMD in the Bachok District over a 5-year period (2018 to 2022). The goal is to inform tailored prevention strategies and develop effective health promotion strategies for the local context, especially because vaccinations are not yet available in Malaysia.

METHODS

Study setting

A cross-sectional study was conducted based on mandatory notifications of HFMD, hereafter referred to as 'notifications', submitted to the Bachok District Health Office from 2018 to 2022. This study used 5 years of retrospective data to conduct a thorough and reliable analysis of HFMD trends. The

extended timeframe captured both short-term fluctuations and long-term patterns, accommodating seasonal variability and significant public health events. Bachok is a district in the state of Kelantan, Malaysia, located approximately 25 km east of Kota Bharu, the capital city. The district has long sandy beaches along its coastline facing the South China Sea and covers an area of 279 km². With a population of 130,334, it has a nearly equal gender distribution.¹⁴ Bachok was chosen as the study area due to a substantial increase in HFMD incidence in 2022 and its proximity to Kota Bharu, serving as a satellite district to the capital. Additionally, Bachok's unique environmental factors as a coastal area provide a distinctive context for examining the ecological determinants of HFMD. The district is divided into eight subdistricts, as illustrated in Figure 1.

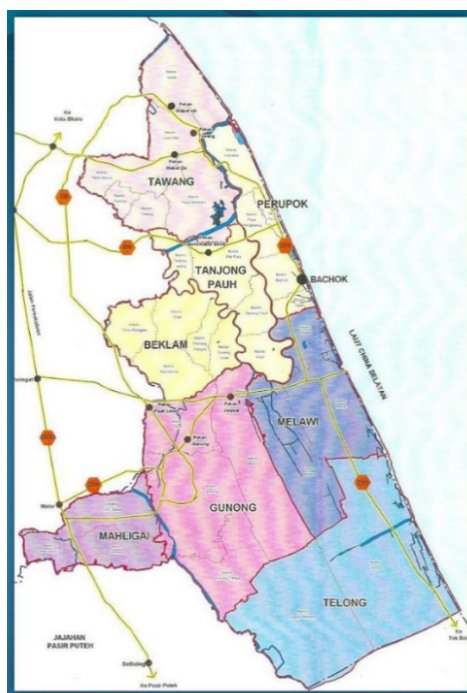


Figure 1. Distribution of subdistricts in Bachok District.

Criteria for sample selection

The inclusion criteria for the study were focused on notifications from individuals aged 10 years and younger. This age restriction was chosen to ensure a

targeted analysis of HFMD within a specific demographic, in line with the *Case Definitions of Infectious Diseases in Malaysia, 3rd Edition*.¹⁵ Conversely, the exclusion criteria were designed to refine

the dataset by removing duplicate notifications and instances with missing data. This approach aims to eliminate redundancy and improve data accuracy, thereby contributing to a more precise and robust analysis.

Sample size determination and sampling method

The sample size for this study was determined using a web-based calculator that calculates using single proportions for estimation and two proportions for hypothesis testing. The calculation assumed a Type I error rate of 5%, a Type II error rate of 20%, and included a 10% margin to account for data errors.^{16,17} The resulting total sample size required was 990 samples. However, due to the retrospective nature of this study, all notifications that met the specified inclusion and exclusion criteria were included, ensuring a comprehensive analysis of the relevant data. The sampling frame included all notifications recorded in the Communicable Disease Control Information System (CDCIS) by the Bachok District Health Office from 2018 to 2022.

Data collection and research tools

In this study, we used the CDCIS, also known as e-Notifikasi. This system is a network designed for the notification and monitoring of communicable diseases, connecting healthcare facilities, including both private and government-operated clinics and hospitals, with the Communicable Disease Control Units at Bachok District Health Offices. All cases of infectious diseases, including HFMD, are promptly reported to the nearest district health office in accordance with the Prevention and Control of Infectious Diseases Act 1988 (Act 342). The system enables the immediate transmission of notification data from healthcare facilities

to e-Notifikasi, ensuring direct access at the district level without delays, which is more efficient than traditional notification forms. The use of CDCIS, a comprehensive and integrated system, has proven to be effective and serves as a reliable data source for this study. No personal information was included in the dataset to maintain anonymity. The data underwent thorough examination to ensure it met the inclusion and exclusion criteria, followed by detailed data cleaning and exploration processes.

Clinically, a case of HFMD was identified as any child aged 10 or below who exhibits ulcers in the mouth or on the tongue and maculopapular rashes and/or vesicles on the palms and soles, with or without a history of fever.¹⁵ Notifications meeting these clinical criteria were recorded and registered as HFMD cases, hereafter referred to as 'cases' in the CDCIS, whereas those not meeting this definition were categorised as having other diseases. The duration of health-seeking was defined as the number of days between the onset of symptoms and diagnosis. Monsoon seasons in Bachok were categorised according to the Malaysian Meteorological Department's announcements, with the Southwest Monsoon spanning May to September, the Northeast Monsoon from November to March, and the Inter Monsoon periods in April and October each year.¹⁹ The first Movement Control Order (MCO) was announced on 18 March, 2020. Thus, notifications in the CDCIS before the MCO announcement were classified as prior to MCO, and those after were classified as post MCO.²⁰

Statistical analysis

Data for this study were analysed using R Software.²¹ Descriptive statistics were used to summarise the sociodemographic characteristics of the notifications. Numerical data are presented

as means (standard deviation, SD) and categorical data as frequencies (percentage). Annual incidence rates were calculated by dividing the number of cases by the total population of Bachok, as estimated by the Department of Statistics Malaysia. Due to limitations in obtaining specific population data for children aged under 10 years, the total population was used in calculations. The 5-year annualised incidence rate was computed to provide a standardised measure of HFMD incidence throughout the study period, accounting for yearly fluctuations and offering a comprehensive overview of the disease's impact. Longitude-latitude coordinates of the cases were exported to QGIS version 3.3 for spatial analysis,²² visually illustrating the annual distribution of cases across sub-districts over the 5-year period using a heat map. Statistical analyses included multiple logistic regression to identify the determinants of HFMD. Initial analysis involved simple logistic regression for each independent variable, with results presented as crude odds ratios (ORs). Variables with p values less than 0.25, or those considered clinically important, were selected for further analysis. Goodness of Fit tests were conducted to ensure the model's appropriateness. The findings are presented as adjusted ORs (Adj. ORs).

Ethical approval

This study was approved by the Medical Research and Ethics Committee with the research identification of NMRR ID-23-02519-NM4 on 20 October 2023 through its letter with reference number of 23-02519-NM4 (2).

RESULTS

The Bachok District Health Office received a total of 1628 notifications. After rigorous screening, 45 notifications (2.76%) were excluded because they involved individuals over the age of 10 years, thus not meeting the age-specific inclusion criteria. Additionally, 208 notifications (12.78%) were excluded due to duplication, and another 24 notifications (1.47%) were omitted because of missing data. Finally, 1351 notifications were included in the analysis.

Sociodemographic characteristic of notifications

A retrospective descriptive analysis was conducted on the sociodemographic characteristics of 1351 notifications from the Bachok District Health Office covering the years 2018 to 2022. The average age of the individuals notified was 2.69 years, with men accounting for 56.7% of the notifications. The majority of notifications involved the Malay population, comprising 99.2% of the total. Outpatient care was the predominant treatment approach, utilised in 98.4% of notifications, with primary health clinics being the most frequently visited healthcare facilities (70.9%). The average duration from symptom onset to seeking medical attention was 1.56 days, with a standard deviation of 1.35 days. Most of the notified individuals (80.4%) were cared for at home, whereas 12.8% were daycare attendees. The Northeast Monsoon period recorded the highest number of notifications, representing 40.3% of the total. Following the implementation of the MCO, 60.2% of the notifications were recorded. Out of 1351 notifications, 840 were classified as HFMD cases. Table 1 provides a detailed summary of all the sociodemographic characteristics of the notifications recorded at the Bachok District Health Office.

Table 1. Descriptive Sociodemographic Characteristics of Notifications at Bachok District Health Office (2018 to 2022, n = 1351).

Variable	Overall n (%)	Cases n (%)	Other Disease n (%)
Age (years old)^a	2.69 (2.20)	2.60 (2.07)	2.83 (2.39)
Sex			
Male	766 (56.7)	471 (56.1)	295 (57.7)
Female	585 (43.3)	369 (43.9)	216 (42.3)
Race			
Malay	1,340 (99.2)	832 (99.1)	508 (99.4)
Others	11 (0.8)	7 (0.9)	3 (0.6)
Healthcare Facility			
Government Hospital	198 (14.7)	106 (12.6)	92 (18.0)
Private Hospital	8 (0.6)	4 (0.5)	4 (0.8)
Primary Health Clinic	958 (70.9)	612 (72.9)	346 (67.7)
Private General Practitioner	187 (13.8)	118 (14.0)	69 (13.5)
Treatment Status			
In-Patient	21 (1.6)	12 (1.4)	9 (1.8)
Outpatient	1,330 (98.4)	828 (98.6)	502 (98.2)
Subdistrict			
Bekelam	91 (6.7)	55 (6.5)	36 (7.0)
Gunong	255 (18.9)	163 (19.4)	92 (18.0)
Mahligai	97 (7.2)	55 (6.5)	42 (8.2)
Melawi	147 (10.9)	96 (11.4)	51 (10.0)
Perupok	201 (14.9)	110 (13.1)	91 (17.8)
Tanjong Pauh	119 (8.8)	82 (9.8)	37 (7.2)
Tawang	311 (23.0)	189 (22.5)	122 (23.9)
Telong	130 (9.6)	90 (10.7)	40 (7.8)
Education Institution			
Homecare	1,086 (80.4)	671 (79.9)	415 (81.2)
Daycare	173 (12.8)	124 (14.8)	49 (9.6)
Primary Schools	92 (6.8)	45 (5.4)	47 (9.2)
Duration of health-seeking (days)^a	1.56 (1.35)	1.56 (1.24)	1.56 (1.51)
Monsoon			
Inter Monsoon	176 (13.0)	104 (12.4)	72 (14.1)
Southwest Monsoon	809 (59.9)	513 (61.1)	296 (57.9)
Northeast Monsoon	366 (27.1)	223 (26.5)	143 (28.0)
MCO			
Post MCO	813 (60.2)	447 (53.2)	366 (71.6)
Pre MCO	538 (39.8)	393 (46.8)	145 (28.4)

^aMean (SD)

Temporal trends of cases

The trend in case numbers and incidence rates from 2018 to 2022 shows significant fluctuations. In 2018, there were 212 cases with an incidence rate of 132.25 per 100,000 population. This number decreased to 106 cases (incidence rate of 65.15) in 2019 and further declined to 84 cases (incidence rate of 53.40) in 2020. In 2021, only 3 cases were reported, corresponding to an incidence rate of 1.89

per 100,000 population. However, there was a sharp increase in 2022, with 436 cases resulting in an incidence rate of 272.16 per 100,000 population. Thus, the 5-year average annual incidence rate of HFMD in the Bachok District was approximately 104.97 per 100,000 population. Figure 2 illustrates the monthly patterns of notifications and cases, alongside the annual incidence rates.

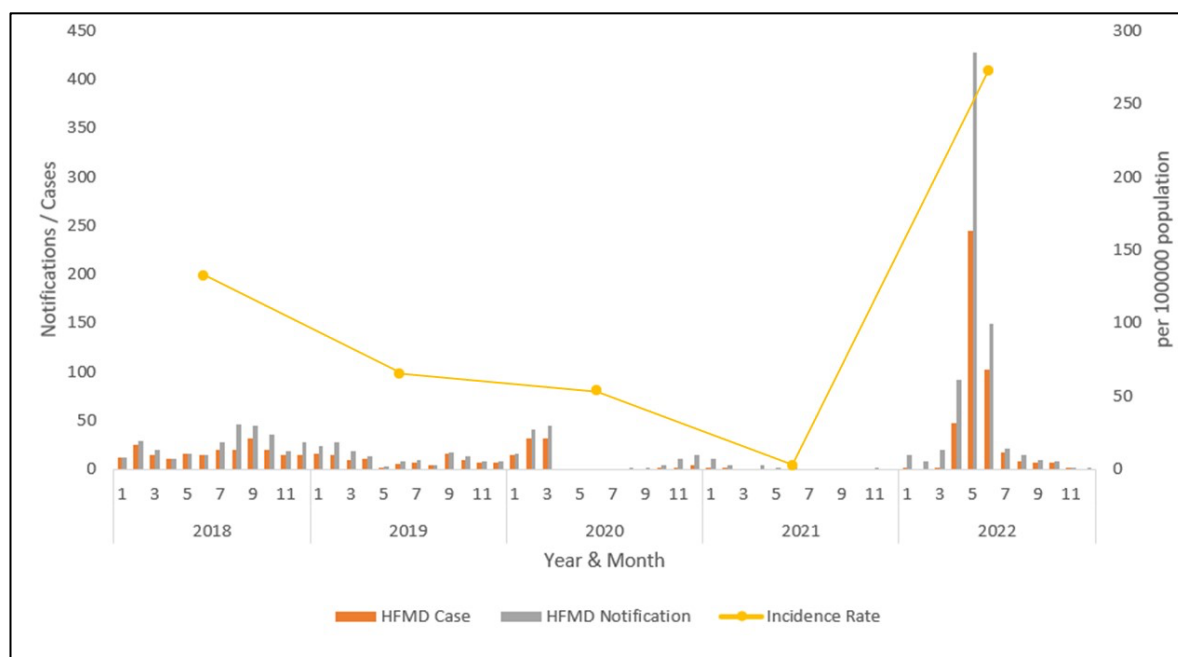


Figure 2. Temporal patterns of notifications, cases, and incidence cases

Spatial trends of Cases

The data revealed significant variation in the number of HFMD cases across different subdistricts and years within the Bachok District. Except for 2021, the Tawang subdistrict consistently reported the highest annual number of cases among the eight subdistricts, with a peak of 94 cases in 2022, contributing to a total of 189 cases over the five-year period. In 2021, Tanjung Pauh recorded the highest number of cases among the subdistricts. However, Bekelam subdistrict consistently showed the lowest case count, with only 55 cases reported over the 5-year period. There were several instances in 2021 where no

cases were reported in various subdistricts. Table 2 provides a detailed breakdown of cases from 2018 to 2022 across the eight subdistricts. Figure 3 displays heat maps illustrating the annual spatial distribution of cases. The hotspots were initially most prominent in Tawang in 2018 and expanded to include neighbouring subdistricts Tanjung Pauh and Perupok in subsequent years. However, there was a shift in case concentration in 2020 before significantly reducing to only three localities in the following year. In 2022, the hotspots were more spread out, with the highest concentrations detected along the border between Perupok and Melawi subdistricts.

Table 2. Distribution of cases for each subdistrict at Bachok District (2018 to 2022, n = 840).

Subdistrict	Year					Grand Total
	2018	2019	2020	2021	2022	
Bekelam	8	5	9	0	33	55
Gunong	39	19	15	0	90	163
Mahligai	21	12	4	0	18	55
Melawi	18	13	11	1	53	96
Perupok	24	16	10	0	60	110
Tanjong Pauh	22	13	8	2	37	82
Tawang	55	22	18	0	94	189
Telong	25	6	9	0	50	90
Grand Total	212	106	84	3	435	840

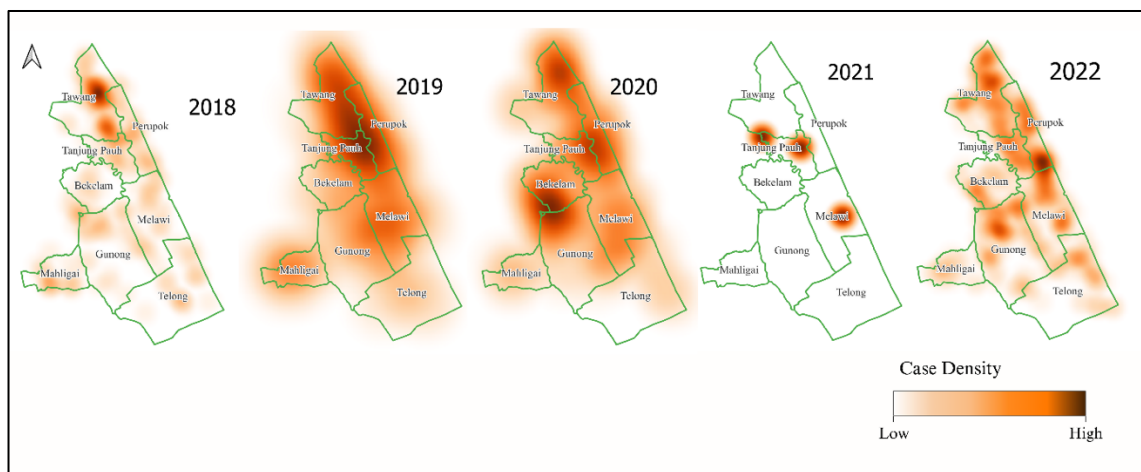


Figure 3. Geographical distribution of cases in Bachok from 2018 to 2022 using heat maps.

Determinants of Cases

A simple logistic regression was conducted to identify variables with both a p value below 0.25 and clinical significance, which were then included in a multiple logistic regression. The key determinants of HFMD occurrence in Bachok District, Kelantan, include the type of healthcare facility attended, daycare attendance, the Southwest Monsoon season, and the period before the MCO. The final model revealed that children attending primary health care facilities had 1.84 times higher odds of children being HFMD cases (Adj. OR: 1.84, 95% Confidence Interval (CI): 1.32, 2.58, $p < 0.001$) compared with

those attending government hospitals. Similarly, children seeking care from private general practitioners exhibit double the odds of contracting HFMD (Adj. OR: 2.10, 95% CI: 1.35, 3.29, $p = 0.001$). Children in daycare settings had 2.10 times higher odds of children being HFMD cases compared with those cared for at home (Adj. OR: 2.10, 95% CI: 1.41, 3.17, $p < 0.001$). The Southwest Monsoon season was associated with 1.5 times higher odds of HFMD cases compared with the Inter Monsoon season (Adj. OR: 1.49, 95% CI: 1.04, 2.12, $p = 0.029$). Furthermore, the period preceding the implementation of the MCO was strongly linked to nearly four

times higher odds of HFMD cases compared with the period following the MCO (Adj. OR: 3.78, 95% CI: 2.81, 5.14, $p < 0.001$), controlling for other factors.

Table 2 presents detailed findings from both the simple and multiple logistic regressions conducted in this study.

Table 3. Simple and multiple logistic regression of determinants to HFMD in Bachok District, Kelantan (n=1351)

Variable	Crude OR (95%CI)	p-value	Adjusted OR (95%CI)	p-value
Age (years old)^a	0.95 (0.91, 1.00)	0.062	0.95 (0.88, 1.03)	0.247
Sex				
Male	Ref			
Female	1.07 (0.86, 1.34)	0.551		
Race				
Others	Ref			
Malay	0.61 (0.13, 2.13)	0.473		
Healthcare Facility				
Government Hospital	Ref		Ref	
Private Hospital	0.87 (0.20, 3.76)	0.844	1.16 (0.26, 5.27)	0.841
Primary Health Clinic	1.54 (1.13, 2.09)	0.007	1.84 (1.32, 2.58)	<0.001
Private General Practitioner	1.48 (0.99, 2.24)	0.058	2.10 (1.35, 3.29)	0.001
Treatment Status				
In-Patient	Ref			
Outpatient	1.24 (0.50, 2.94)	0.632		
Subdistrict				
Bekelam	Ref		Ref	
Gunong	1.16 (0.71, 1.89)	0.555	1.10 (0.65, 1.85)	0.709
Mahligai	0.86 (0.48, 1.53)	0.603	0.67 (0.36, 1.23)	0.197
Melawi	1.23 (0.72, 2.11)	0.449	1.17 (0.66, 2.07)	0.581
Perupok	0.79 (0.48, 1.31)	0.362	0.76 (0.45, 1.29)	0.318
Tanjong Pauh	1.45 (0.82, 2.58)	0.202	1.25 (0.68, 2.28)	0.472
Tawang	1.01 (0.63, 1.63)	0.954	0.86 (0.52, 1.42)	0.569
Telong	1.47 (0.84, 2.59)	0.177	1.32 (0.73, 2.39)	0.352
Education Institution				
Homecare	Ref		Ref	
Daycare	1.57 (1.11, 2.24)	0.013	2.10 (1.41, 3.17)	<0.001
Primary Schools	0.59 (0.39, 0.91)	0.016	0.85 (0.44, 1.66)	0.638
Duration of health seeking (days)^a	1 (0.92, 1.09)	0.964		
Monsoon				
Inter Monsoon	Ref		Ref	
Southwest Monsoon	1.20 (0.86, 1.67)	0.283	1.49 (1.04, 2.12)	0.029
Northeast Monsoon	1.08 (0.75, 1.56)	0.682	0.67 (0.44, 1.00)	0.051
MCO				
Post MCO	Ref		Ref	
Pre MCO	2.22 (1.76, 2.81)	<0.001	3.78 (2.81, 5.14)	<0.001

Hosmer Lemeshow test, p-value: 0.319

Classification accuracy: 67.3 %

The area under Receiver Operating Characteristic (ROC): 0.67

DISCUSSION

HFMD is a major public health concern, necessitating a comprehensive understanding of its epidemiology to safeguard public health, particularly in regions with a substantial disease burden. In the Bachok District, the 5-year average annual incidence of HFMD is approximately 104.97, a figure comparable to that of the state of Sabah in Malaysia but considerably lower than that of Nanjing Province (231 cases/100,000), China.^{4,23} Factors such as hygiene practices and reporting mechanisms lead to variations in incidence rates between China and Malaysia. Between 2018 and 2020, the trend in cases consistently displayed two peaks annually. This pattern is attributable to stable climatic conditions and regular school and holiday schedules, which affect the cyclical nature of HFMD outbreaks. The consistency in these external factors contributed to the predictable peaks in case numbers. However, during 2021, a considerably low number of cases was recorded. This significant reduction can be primarily attributed to the MCO implemented in response to the COVID-19 pandemic, specifically from 18 March 2020 onwards. The MCO enforced strict measures, including school closures, social or physical distancing, and restrictions on public gatherings.²⁰ These interventions reduced opportunities for HFMD transmission by limiting close contact and social interactions, which are critical for the spread of the virus. Following the easing of MCO restrictions and the return to normal activities, a sharp increase in cases was observed in 2022. This resurgence is linked to the return to pre-pandemic levels of social and public activities that created conducive conditions for HFMD transmission, leading to a significant spike in cases. An analysis of spatial distribution revealed that the Tawang subdistrict

exhibited the highest number of cases and hotspots from 2018 to 2020 and again in 2022 compared with other subdistricts. A potential reason for the spread of HFMD could be the high population mobility in the subdistrict's closest proximity to the capital city of Kelantan, coupled with the slightly high population density. This interaction likely facilitated the transmission of HFMD, as reported in similar studies conducted in China, Terengganu, and Sabah.^{4,24,25}

Our findings from the multiple logistic regression model revealed that attending primary healthcare facilities and private general practitioners are significant determinants of where children with HFMD seek medical care when compared with those attending government hospitals. This suggests that healthcare-seeking behaviour, the self-limiting nature of the disease, and the accessibility of these facilities are likely influencing factors in the location of diagnosis.² HFMD is characterised as a self-limiting disease, meaning it typically resolves on its own, with or without treatment, and is usually mild.² We hypothesised that the absence of both government and private hospitals in the Bachok district influences parents' healthcare choices, with proximity to primary healthcare facilities being a key factor. Parents with young children affected by HFMD may prefer private general practitioners for their convenience, including extended after-hours services. Conversely, the public sector also exhibits higher odds of diagnosing HFMD due to its comprehensive healthcare services and better coordination.^{14,26} This preference leads to increased odds of HFMD diagnoses at primary healthcare facilities compared with government hospitals. This analysis indicates that healthcare-seeking behaviour is an important determinant in the management and reporting of cases, rather

than a direct influence on the initial risk of contracting the infection.

Numerous previous studies have linked children's attendance at daycare facilities to an increased risk of various infections, such as upper respiratory tract infections, acute otitis media, acute pneumonia, and gastroenteritis. Until now, there has been no established link between daycare attendance and HFMD.²⁷ However, this study identified a significant association between attending daycare and an increased risk of HFMD, suggesting that HFMD should be considered one of the infections associated with daycare attendance. Laor et al., in a study conducted in Northern Thailand, found that daycares not meeting specific standards related to the number of restrooms, sinks per child and overall student numbers were more likely to see outbreaks of HFMD.²⁸ Our hypothesis is that the frequent close contact among children in daycare settings facilitates the transmission of HFMD, which is highly contagious. In addition, the risk of contracting HFMD may be increased by the typically limited personal hygiene practices observed among young children in daycares.

Numerous studies have demonstrated the significant impact of climate on the occurrence of HFMD, with temperature, humidity, and rainfall identified as pivotal factors influencing the seasonality of the disease.^{12,29} Our study highlights a notable association between HFMD occurrence and the monsoon season. This finding is consistent with models from the west coast of Malaysia, particularly in Selangor, where HFMD cases peak during the Southwest monsoon.³⁰ Notably, the Southwest Monsoon is typically drier across the country, including in the Bachok district. During this period, Bachok experiences minimal monthly rainfall, usually between 100 and 150 mm, and has more rainless days than rainy days.¹⁹ While the exact meteorological mechanisms affecting

HFMD are not fully understood, plausible explanations exist. Elevated temperatures during the dry season may enhance the survival of the enteroviruses in the external environment. Additionally, children are likely to spend more time outdoors during this drier period in Malaysia, which could increase the risk of transmission.^{12,31}

The implementation of the MCO in Malaysia has significantly influenced the transmission dynamics of infectious diseases, including HFMD. This study highlights the unexpected impact of the MCO on HFMD transmission dynamics.²⁰ Specifically, the period preceding the MCO is associated with nearly four times higher odds of cases compared with the period following the MCO. The pre-MCO era was characterised by normal social interactions and movement patterns, which are critical for HFMD transmission. The higher incidence of HFMD cases during this period emphasises how unrestricted social behaviour and mobility facilitate the spread of the virus.²⁴ Conversely, the period during and after the MCO saw substantial restrictions on movement and social interactions, leading to a decrease in HFMD cases. Public health measures implemented as part of the MCO, including campaigns to enhance hygiene awareness such as regular handwashing, played a crucial role in the overall COVID-19 control strategy. These campaigns likely contributed to the reduction in HFMD cases by promoting behaviours that mitigate the transmission of the virus, which spreads through contact with respiratory secretions, feces, or contaminated surfaces.^{2,29}

RECOMMENDATION

Based on our study findings, we propose several targeted health promotion strategies to effectively manage HFMD in the Bachok District. Enhancing public awareness and education is essential. We recommend launching comprehensive

awareness campaigns aimed at those directly involved in childcare, such as parents, guardians, daycare caregivers, and teachers. These campaigns should focus on educating about HFMD symptoms, transmission methods, and preventive measures. The district health office could utilise social media platforms, daycare-parents messaging groups, and community outreach programmes to maximise the reach of these campaigns. Additionally, educational programmes should be implemented in daycare centres to teach children about personal hygiene practices, emphasising regular handwashing. Furthermore, we suggest organising town hall meetings with daycare caregivers and teachers, in collaboration with the Department of Education and the Department of Social Welfare, which oversee these facilities. These meetings would focus on guiding them in implementing effective gatekeeping procedures to reduce the likelihood of HFMD spread in daycare environments.

In addition to enhancing public awareness, promoting hygiene and sanitation is crucial in controlling HFMD in the Bachok District. We recommend implementing community-based hygiene programmes, particularly in high-risk areas such as the Tawang subdistrict. These programmes could involve distributing hygiene kits, including soap and hand sanitizers, to households with young children to improve overall sanitation. Furthermore, daycare centres should adhere to stringent hygiene standards. Regular inspections should be conducted to ensure these facilities comply with cleanliness and sanitation guidelines. Seasonal preparedness is also essential for effective HFMD management. Health promotion activities should be intensified during the Southwest Monsoon season, a time when the risk of transmission may increase. These campaigns should focus on

reinforcing hygiene practices and preventive measures specifically tailored to this period, aiming to mitigate the spread of HFMD.

These health promotion strategies should be targeted and prioritised, especially during times when human and financial resources are limited. By concentrating efforts in high-risk areas and during peak transmission seasons like the Southwest Monsoon season, resources can be allocated more efficiently to maximise impact. Initiatives such as public awareness campaigns, stringent hygiene enforcement in daycare centres, and community-based hygiene programmes ensure that efforts are concentrated where they are most needed. This targeted approach helps to mitigate the spread of HFMD more effectively, even under resource constraints. Furthermore, collaboration with local health authorities, educational institutions, and social welfare departments is crucial. Such partnerships can enhance the reach and sustainability of these initiatives, ensuring they continue to protect vulnerable populations over the long term.

Study Strength and Limitation

This study utilises the CDCIS, a network designed for the notification and monitoring of communicable diseases. The CDCIS is a web-based application implemented by the Disease Control Division of the Ministry of Health Malaysia and is accessible only to registered, authorised public health officers. This system provides a reliable and integrated source of data, enhancing the credibility of the study by ensuring the accuracy and timeliness of the information on communicable diseases. The use of a standardised system such as the CDCIS allows for the reproducibility of the study across various defined populations. Researchers in different regions or countries can adopt a similar approach,

utilising their respective disease surveillance systems, to conduct comparable studies on the trends and dynamics of diseases like HFMD. Additionally, the retrospective cross-sectional design of this study allows for the exploration of trends and associations over a specific period, providing valuable insights into the dynamics of HFMD within the defined population.

This study does not fully address the multifaceted impact of Malaysia's diverse cultural festivals and extended school holidays on the transmission of HFMD. Zhao and Hu (2019) in China highlighted the influence of school terms and the Chinese Spring Festival on HFMD seasonality³². In Malaysia, major celebrations such as Eidulfitri, Chinese New Year, and Deepavali involve extended periods of increased social interactions and mass movements, which could significantly influence HFMD transmission patterns. The exclusion of a detailed analysis of the dynamics associated with these festivals and school holidays in this study limits a comprehensive understanding of HFMD epidemiology in Malaysia. Future research should investigate the nuanced relationships between cultural events, school breaks, and disease transmission to provide a more thorough insight into the seasonal patterns of HFMD in this culturally diverse population.

A potential explanation for the unusual trends in HFMD case numbers could be linked to specific national events. For example, in 2018, Malaysia experienced a significant HFMD outbreak that affected over 76,000 children nationwide. This outbreak had a profound impact on local communities, leading to a surge in cases in the region. While our study effectively investigates the impact of the Movement Control Order (MCO) period, it does have limitations in capturing the influence of other events that may contribute to unusual patterns. For instance, it does not address the effects of significant

events such as the movement of individuals traveling to various locations for voting during Malaysia's 14th General Election in 2018 and the 15th General Election in 2022, both of which could have influenced disease transmission dynamics.

CONCLUSIONS

The integrative approach of this study indicates the complex interplay of biological and ecological determinants that affect health and disease dynamics. Notably, the incidence of HFMD in the Bachok District peaked in 2022, with the Tawang sub-district consistently reporting the highest number of cases. Key determinants of HFMD identified in this study include attendance at primary healthcare or private practitioners, daycare attendance, the Southwest Monsoon season, and the period preceding the implementation of the MCO. This research advocates for a multidisciplinary approach to designing interventions and health promotion strategies. It recommends focusing public health efforts on primary healthcare settings and daycare facilities, particularly during the Southwest Monsoon season. Additionally, it emphasises the importance of prioritising these strategies during times when human and financial resources are limited.

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CONFLICT OF INTEREST

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AUTHORS' CONTRIBUTIONS

Conceptualization: MFMB, RAS; Data curation: NMAH, IAM, SM; Formal analysis: MFMB, NMAH, IAM, SM; Investigation: MFMB, AFMK; Methodology: MFMB, MA, NMY; Project administration: RAS, MZAA; Software: MFMB, AFMK; Supervision: RAS, SMH; Validation: MA, RAS; Visualization: NMAH, MZAA; Writing—original draft: MFMB; Writing—review & editing: all authors.

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