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Epidemiological patterns and impacts of foot and mouth disease in ruminants: A retrospective analysis of 2006-2023 in Palestine

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Abstract

This study presents a retrospective epidemiological analysis of foot and mouth disease (FMD) in ruminants in Palestine from 2006 to 2023. Data from the Palestinian Central Bureau of Statistics, the Annual Agricultural Census, and reports from the World Organization for Animal Health indicated the endemic nature of FMD in Palestine throughout the study period. The findings unveil FMD's consistent presence, reporting outbreaks every year. The comprehensive analysis encompasses 202 outbreaks, involving 5635 cases and 84 deaths, underscoring the disease's substantial impact. The average morbidity, mortality, and case fatality rates were 17.0, 2.2 and 1.49%, respectively. Serotypes O, A, Asia 1, and SAT 2 were identified, each exerting varying effects on morbidity, mortality, and susceptible livestock. Annual trends displayed unpredictable fluctuations in outbreaks, emphasizing the erratic nature of FMD occurrences. Vaccination efforts exhibited fluctuating coverage levels, hinting at potential shifts in strategies or challenges in maintaining consistent programs. Concerningly, recent years witnessed a decline in vaccination, signaling a need for sustained vigilance and strengthened vaccination initiatives to manage FMD's impact on susceptible animal populations effectively. To control disease spread, the study advocates for improved data recording, heightened owner awareness, increased FMD vaccine utilization, and the implementation of a systematic disease monitoring and serotyping program.

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Introduction

Foot and Mouth Disease (FMD) in Palestine poses a highly infectious threat to a diverse range of cloven-hoofed animals, spanning livestock and wildlife species (1). The disease has been classified as a reportable disease by the World Organization for Animal Health (WOAH, formerly OIE), and its impact resonates profoundly, leading to substantial economic losses across various sectors (2). FMD outbreaks trigger direct losses in livestock profitability, including decreased milk and meat production and amplified treatment and control costs (3). Additionally, these outbreaks disrupt the animal and animal products trade, both locally and internationally, exacerbating economic impacts (4). The causative agent, FMDV, a non-enveloped, positive-sense, single-stranded RNA virus, belongs to the *Aphthovirus* genus within the *Picornaviridae* family. It manifests as seven immunologically distinct serotypes A, O, C, Asia 1, and SAT 1, 2 and 3 (Southern African Territories) each with diverse pathotypes (5). Clinically, FMD is manifested in various symptoms, including fever, anorexia and depression, cessation of rumination, and a notable loss of appetite, decline in milk production, coupled with symptoms such as serous nasal discharge, severe salivation, and observable signs like smacking of lips (6). The disease is also associated with mastitis and abortion in afflicted animals (7). Characteristics of FMD are the development of vesicular lesions and erosions across multiple anatomical sites,

notably in the oral cavity, inter-digital skin in the hooves, coronary band, teat, and muzzle (6). Additionally, the disease triggers claw sloughing and myocardial degeneration, often resulting in fatal outcomes, particularly among young animals (8,9). The morbidity rate can reach an alarming 100%, with mortality soaring to distressing levels in young animals, while adult mortality remains relatively low (8). The global prevalence of FMD spans developing regions, notably Asia, the Middle East, and Africa, where limited veterinary services and resources hinder effective control or eradication (10,11).

While extensive data on FMD from various countries, particularly in Asia, sheds light on its occurrence and prevalence; Palestine remains unexplored in understanding the disease pattern. Remarkably, no systematic investigation into FMD among livestock in Palestine has been conducted. Hence, this study aims to fill this critical gap by analyzing the epidemiological landscape of FMD in Palestine over a comprehensive 17-year period.

Materials and methods

The quantitative data on FMD outbreaks, cases, deaths, serotypes, and vaccinations were collected from 2006 to 2023. Data were based on reports of the World Animal Health Information System (https://wahis.woah.org) submitted by the General Directorate of Veterinary Services and Animal Health between 2006 and 2023.

Ethical approve

All methods and procedures used in a recent study were completed according to the Scientific Ethical Committee on Animal Experimentation guidelines at the Faculty of Agriculture and Veterinary Medicine, An-Najah National University, Nablus, Palestine.

Data statement

The data that support the findings of this study are available on the World Animal Health Information Database (WOAH-WAHIS) Interface: https://wahis.woah.org/#/home

Data analysis

The frequency of the outbreaks, morbidity, mortality, case fatality, and vaccination history rates of FMD were considered each month according to standard methods (12). These epidemiological parameters were calculated according to the following formulae: Morbidity% = amount of cases/ Number of susceptible animals during the outbreak X100, Mortality%= number of deaths /Number of susceptible animals during the outbreak X100, and Case fatality%= number of deaths /number of cases during the outbreak X100. The data collected were analyzed using Microsoft Office Excel (2007), and figures were performed using GraphPad Prism 5 software (GraphPad Software Inc., San Diego, USA).

Results

Cumulative profile

Over 17 years in Palestine, table 1 presents a comprehensive retrospective view of FMD through quantitative data. This dataset revealed the documentation of 202 outbreaks encompassing 5,635 cases and resulting in 84 deaths in ruminants. Susceptible animals include cattle, sheep, and goats. The reported serotypes included O, A, Asia 1, and SAT 2. The average morbidity and mortality were 17.0 and 2.2% respectively. Additionally, the average case fatality rate was 1.49%. However, it is essential to note that data for the year 2008 was unavailable, potentially leaving a gap in the analysis of this crucial period.

FMD Annual trends

Our finding showed that FMD outbreaks occurred in all years (Figure 1 and Table 1), with the highest number occurring in 2011 (n=30) and in 2014 (n=40). The prevalence of FMD in Palestine fluctuated significantly over the recorded years. They started with five new outbreaks in 2006. Subsequently, the occurrences varied, with notable peaks in 2011, recording 30 outbreaks; the numbers spiked in 2014 with a staggering 40 outbreaks and a substantial decrease in 2019 with only one outbreak. The pattern continued with intermittent fluctuations, showcasing the erratic nature of FMD in the region, as seen in 2017 with 11 outbreaks, followed by a drop to just four outbreaks in 2018 and 2020.

Serotypes distribution

The data on FMD in Palestine from 2006 to 2023 showcases various outbreaks, each year characterized by different serotypes and their corresponding impacts). The years were marked by diverse serotypes driving outbreaks: from un-typed cases in 2006 to a mix of A, Asia 1, and O in 2007, illustrating 20 outbreaks affecting a considerable susceptible population of 4,725 animals. 2014 showed a significant surge in outbreaks driven solely by serotype O, impacting 8,411 susceptible animals. Interestingly, while 2018 had only four outbreaks, the morbidity rate was notably high at 46.4% within a population of 481 susceptible animals caused by serotype O. Additionally, 2022 recorded five outbreaks predominantly caused by serotype O, affecting 2,145 susceptible animals but resulted in a higher mortality rate due to 69 deaths.

Temporal distribution

Data for various parameters were collated monthly from January 2006 to December 2023. During this period, the 2disease occurred in all months of the year (Table 2 and Figure 2). The outbreaks varied in frequency and impact. The highest number of outbreaks occurred in December (n=47), February (n=25), and March (n=24), while the lowest was recorded in August (n=5), October (n=10), and June (n=9).

Morbidity rates fluctuated notably, with peaks in August 54.1% and June 43.5%, indicating a high proportion of reported cases relative to the susceptible population. Case fatality rates showed considerable variability, with July exhibiting the highest rate at 47.0% and October and September recording a 0% case fatality rate (Table 2).

Table 1: Annual statistics of FMD in cattle, sheep, and goats in Palestine 2006-2023

Year	Number				Serotype	%		
	Total	Susceptible	Cases	Deaths		Morbidity	Mortality	Case fatality
2006	5	1,188	278	10	not typed	23.4	0.8	3.6
2007	20	4,725	869	218	A, Asia 1, O	18.4	4.6	25.1
2009	19	2,541	165	5	A, O	6.5	0.2	3.0
2010	1	11	2	0	A, O	18.2	0.0	0.0
2011	30	4,170	546	12	A, Asia 1, O	13.1	0.3	2.2
2012	17	1,487	126	28	SAT 2, O	8.5	1.9	22.2
2013	7	1,163	184	24	SAT 2, O	15.8	2.1	13.0
2014	40	8,411	1,125	129	O	13.4	1.5	11.5
2015	23	3,966	542	268	O	13.7	6.8	49.4
2016	2	625	40	0	O	6.4	0.0	0.0
2017	11	2,640	329	31	O	12.5	1.2	9.4
2018	4	481	223	0	O	46.4	0.0	0.0
2019	1	433	80	10	O	18.5	2.3	12.5
2020	4	310	54	0	O	17.4	0.0	0.0
2021	9	3,045	911	15	O	29.9	0.5	1.6
2022	5	2,145	112	69	O	5.2	3.2	61.6
2023	4	231	49	28	O	21.2	12.1	57.1

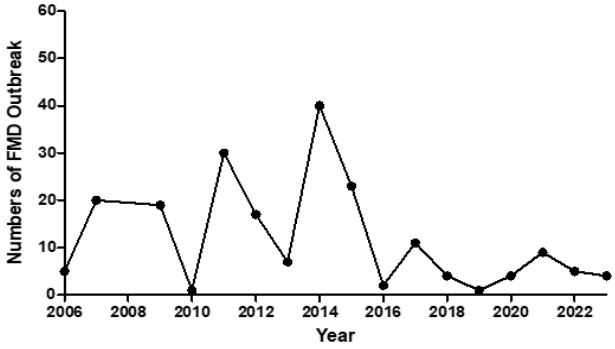

Figure 1: Numbers of FMD outbreaks in cattle, sheep, and goats in Palestine each year 2006-2023.

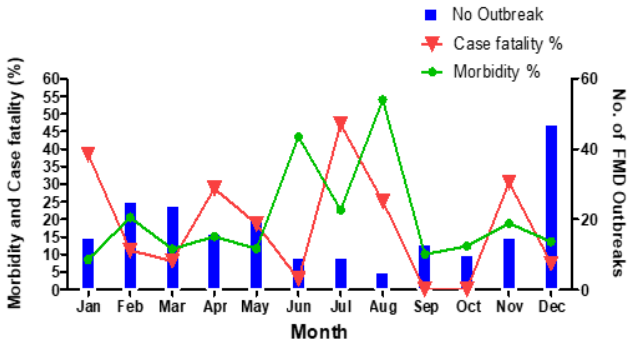

Figure 2: Seasonality of FMD Palestine (January 2006 to December 2023).

Trends in vaccine utilization

Between 2006 and 2013, there were varying but notable numbers of vaccinated animals, showcasing a concerted effort to protect susceptible populations against FMD (Figure 3). However, in 2014, 2015, and 2016, there were no records of vaccinated animals. Subsequently, there was a resurgence in vaccination efforts in 2017, 2018, and 2019, albeit with relatively lower numbers than previous years. 2020 witnessed a substantial increase in vaccinated animals, reaching 348,055, indicating a renewed emphasis on vaccination programs. However, 2021 and onwards saw a decline in vaccinated animals, with notably lower figures in 2022 and 2023, potentially signaling a concerning decrease in vaccination coverage.

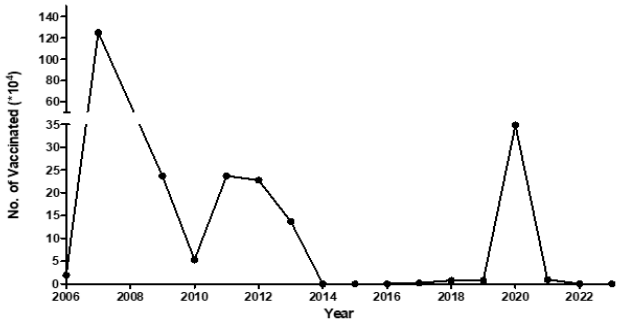

Figure 3: Number of vaccinated animals to FMD in cattle, sheep, and goats in Palestine during 2006-2023.

Table 2: Seasonal indices of monthly FMD outbreaks in cattle, sheep, and goats between 2006 and 2023 in Palestine

Month	Number				Percentage		
	Outbreak	Susceptible	Case	Deaths	Morbidity	Mortality	Case fatality
Jan	15	2255	192	74	8.5	3.3	38.5
Feb	25	5233	1075	120	20.5	2.3	11.2
Mar	24	7846	901	73	11.5	0.9	8.1
Apr	16	2459	372	107	15.1	4.4	28.8
May	20	2265	262	49	11.6	2.2	18.7
Jun	9	563	245	7	43.5	1.2	2.9
Jul	9	1335	302	142	22.6	10.6	47.0
Aug	5	375	203	51	54.1	13.6	25.1
Sep	13	1730	173	0	10.0	0.0	0.0
Oct	10	1172	145	0	12.4	0.0	0.0
Nov	15	1387	262	80	18.9	5.8	30.5
Dec	47	7878	1074	79	13.6	1.0	7.4

Discussion

FMD is a highly contagious viral illness affecting cattle, sheep, and goats. Given its significant economic repercussions in Palestine, analyzing the epidemiological data of this disease is crucial. This study represents the inaugural longitudinal analysis of FMD outbreak distribution in Palestine. Our research uncovered consistent annual FMD outbreaks, totaling 202 confirmed occurrences over 17 years (2006 to 2023) among cattle, sheep, and goats in Palestine. This investigation holds significant importance as it unravels the disease dynamics, mortality rates, mortality, case fatality, and temporal distribution of FMD in Palestine. Additionally, the study aimed to identify the contributing factors responsible for the persistent infection within the region. Understanding these intricacies is crucial, as it provides insights into the disease's behavior and assists in evaluating the associated risks. Such comprehension lays the foundation for devising tailored preventive and responsive measures to curtail infection rates or eradicate the disease (13-15).

The first official report of FMD in the country was in 2006. Since then, many outbreaks have occurred and been documented; this documentation was based on the confirmation of WOAH, the Veterinary Service, and the Ministry of Agriculture laboratories. Indeed, other outbreaks, deaths, and data based on clinical observations were not accurately recorded due to inadequate animal disease diagnosis, reporting, and surveillance systems. The data for outbreaks shows the unpredictable nature of FMD occurrences in Palestine over the years. Our findings indicate that FMD in Palestine is present in an enzootic form with average morbidity and mortality of 17.0 and 2.2%, respectively, reflecting the prevalence of the disease and in agreement with other studies that the mortality rate in endemic areas (16,17). The average case fatality rate was a concerning 1.49%, highlighting the severity of FMD. However, these rates need to be investigated by a national surveillance campaign.

Palestine experienced varying outbreaks of FMD, each year characterized by different serotypes driving the disease's impact. The fluctuating pattern showcased diverse effects, from mixed serotypes of A, Asia 1, and O in 2007 to a surge driven by serotype O in 2014 and a smaller but impactful outbreak in 2018. In 2022, despite fewer outbreaks, serotype O caused higher mortality among susceptible animals due to low vaccination campaigns, highlighting the varied impacts of different serotypes on morbidity, mortality, and susceptible populations over time. Similar estimates confirm that FMD is a regional problem in countries in the Middle East; for example, over five years from July 1999 to June 2004, five outbreaks of FMD serotype O and one outbreak of FMD serotype SAT 2 were reported among livestock in Saudi Arabia. During five outbreaks of FMDV serotype O, a wide range of morbidities 13.6-100%, mortalities 0-0.9%, and case fatalities 0-5% were reported among traditional cattle herds with no data of vaccination against FMD and no history of previous exposure to FMDV infection (16). In 2017, FMD outbreaks were identified in various animal species in Jordan, causing high mortality rates in young lambs and goats and classic FMD symptoms in cattle. The case fatality rates varied widely across farms: 0-19% in cattle farms, 46-77% in sheep farms, 35-68% in mixed farms, and 0-55% in goat farms (17). In Iraq, FMD has plagued Iraq since 1937, presenting as a devastating seasonal epidemic. The circulating serotypes include A, O, and Asia 1, and the investigated FMD patterns in Iraq from 2011 to 2016 among cattle, buffalo, and small ruminants in 15 governorates revealed annual outbreaks with varying infection and mortality rates. In 2016, FMD prevalence was notably higher: 68.7% in cattle, 46.6% in buffalo, and 30.3% in small ruminants compared to lower rates in 2015 (18.4, 19.9, and 17.3%, respectively) (18). The initial occurrences of FMD SAT-2 in Iraq and Jordan, representing the first instances in the Middle East, attributed to SAT 2/XIV. While recent vaccination drives targeted the endemic serotype O in the region, they are not anticipated to

offer protection against serotype SAT-2 (19,20). Serotypes O, A, and SAT 2 have been reported in Egypt. SAT 2 reemerged in 2012, associated with the Sudan 2008 strain, and in recent years have outbreaks of new variations within serotypes O and SAT2 in Egypt, and the seroprevalence surged from 48.30% to 68.10% between 2021 and 2022 (21,22). In Bangladesh, among 3,580 animals investigated between 2012 and 2021, FMD resulted in rates of 54.7% morbidity, 10.4% mortality, and a case fatality rate of 19% (23). The variations in FMD incidence between these countries are mostly related to the different densities of the flocks in the studied area, animal husbandry systems, flock size, vaccinations, humidity, rainfall and temperature, and the technique used for detection of the disease (24,25).

The disease in Palestine is circulating quietly during the season. Our findings show that months with higher FMD activity, like February and December, showcased increased outbreaks, impacting larger susceptible populations and resulting in elevated case and death counts. These peaks might be attributed to various factors, such as environmental conditions favoring viral stability and transmission, such as drying out, pH extremes, and high temperatures (26,27). In addition, changes in animal movement or trading practices or potentially lower vaccination coverage during specific periods (26-29). Conversely, months with fewer outbreaks, like June, August, September, and October, might indicate potential seasonal fluctuations or periods of heightened control measures. Lower temperatures, changes in animal behaviors, or intensified surveillance and vaccination efforts could contribute to these comparatively quieter periods (27). These results agree with other studies that observed higher prevalence in the wet season and after the rain period (30,31). Overall, these findings underscore the dynamic nature of FMD outbreaks in Palestine, highlighting months of intense transmission and differing levels of severity, urging for tailored interventions and surveillance strategies to curtail its impact on livestock.

The trends in FMD vaccine utilization in Palestine reflect a fluctuating pattern over the years. These trends suggest varying levels of commitment to FMD vaccination efforts in Palestine over the years, highlighting potential shifts in priorities or challenges in maintaining consistent vaccination programs. A nationwide control measure for FMD involves a multi-pronged approach. This includes free vaccination programs conducted biannually for cattle and annually for small ruminants, utilizing the multivalent inactivated vaccines of A, O, and Asia1 serotypes (32). It is important to note that the Israeli occupation measures defy access to veterinary services for animals in Palestine. The difficulties in reaching animal holdings near the Israeli settlements and the closed Israeli military areas by Israeli military barriers and checkpoints also contribute to the low vaccination rate (33,34). In addition, the absence of a private veterinary sector role and the restriction of vaccine administration by the Veterinary Service at the Ministry of Agriculture, as well as the unawareness of owners about the benefits of vaccination, could be probable explanations for this low unorganized vaccination numbers (35).

Our study's findings might be skewed due to varying district outbreak reporting rates. We notice missing data and underreporting of FMD outbreaks, potentially introducing bias. Moreover, diseases some outbreaks are diagnosed based on clinical signs and confirmatory tests without serotyping. Nevertheless, our study aimed to provide essential epidemiological insights into FMD's temporal distribution in Palestine, offering valuable information for regional and national FMD control decisions (36). Understanding the reasons behind these fluctuations can help refine disease control strategies, emphasizing the need for heightened vigilance and targeted interventions during high-risk months while sustaining control efforts during quieter periods to manage FMD spread effectively (37-39). Implementing a new animal identification system aims to bolster control alongside efforts to raise public awareness about FMD. Further, the country has invested in advanced laboratory technologies like Rt-PCR, serotype PCR primers, and seroprevalence surveys to enhance disease detection and control capacities (40,41).

Conclusion

In conclusion, our 17-year analysis of Foot-and-Mouth Disease (FMD) in Palestine highlights its substantial impact on livestock health and the dynamic nature of its epidemiology. The cumulative profile, depicting 202 outbreaks and 5635 cases with varying serotypes, emphasizes the need for tailored interventions. Peaks in FMD activity during specific months suggest environmental and behavioral influences on disease transmission. Fluctuations in vaccine utilization over the years, potentially linked to challenges imposed by the Israeli occupation and low awareness among animal owners, underscore the complexity of control efforts. Despite limitations, such as varying reporting rates and potential underreporting, our study provides essential insights for regional and national FMD control. Investing in advanced laboratory technologies and implementing an animal identification system signal positive steps toward enhancing disease detection and control capacities. Overall, this longitudinal analysis serves as a foundation for informed decision-making, urging sustained efforts to manage and mitigate the impact of FMD in Palestine.

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Conflict of interest

The author declares no conflicts of interest.

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الأنماط الوبائية وتأثيرات مرض الحمى القلاعية على المجترات: تحليل استرجاعي للأعوام ٢٠٠٦-٢٠٢٣ في فلسطين

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دائرة الطب البيطري، كلية الزراعة والطب البيطري، جامعة النجاح الوطنية، نابلس، فلسطين

الخلاصة

تقدم هذه الدراسة تحليلاً وبائياً بأثر رجعي لمرض الحمى القلاعية في المجترات في فلسطين خلال السنوات من ٢٠٠٦ إلى عام ٢٠٢٣. أظهرت البيانات المستمدة من التعداد الزراعي السنوي للجهاز المركزي للإحصاء الفلسطيني وتقارير المنظمة العالمية للصحة الحيوانية إلى توطن المرض في فلسطين طوال فترة الدراسة، حيث يتم الإبلاغ عن تفشي المرض كل عام. وتم رصد ٢٠٢ حالة ثورة مرضية، شملت ٥٦٣٥ إصابة نفوق ٨٤ حيوانا، مما يؤكد تأثير للمرض على صحة الحيوانات والإنتاجية في فلسطين. كانت معدلات الاصابة والنفوق ونسبة الحالات النافقة ١٧,٠ و٢,٢ و ١,٤٩% على التوالي. تم تحديد الأنماط المصلية O وA و1 Asia و2 SAT، ولكل منها تأثيرات متفاوتة على معدلات الاصابة والنفوق في الحيوانات المعرضة للإصابة. وأظهرت الاتجاهات السنوية تقلبات لا يمكن التنبؤ بها في حالات تفشي المرض، مما يؤكد الطبيعة غير المنتظمة لحدوث مرض الحمى القلاعية. كما وأظهرت جهود التطعيم مستويات تغطية متقلبة، مما يشير إلى التحولات في الاستراتيجيات أو التحديات في الحفاظ على برامج تطعيم متسقة، ومما يثير القلق أن السنوات الأخيرة شهدت انخفاضاً كبيرا في إعداد التطعيم، مما يشير إلى الحاجة إلى اليقظة المستمرة وتعزيز مبادرات التطعيم لإدارة تأثير مرض الحمى القلاعية بشكل فعال على مجموعات الحيوانات المعرضة للإصابة. وللسيطرة على انتشار المرض، تدعو الدراسة إلى تحسين تسجيل البيانات، وزيادة وعي المزارعين، وزيادة استخدام لقاح مرض الحمى القلاعية، وتنفيذ برنامج منهجي لرصد المرض والتنميط المصلي.

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