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Original Article

" Investigating the Efficacy of Vaccination Programs for Preventing Foot and Mouth Disease in Cattle: A Medical Perspective"

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ABSTRACT

Foot and Mouth Disease (FMD) remains a major threat to global livestock health and agricultural productivity, particularly in regions with endemic circulation. This study evaluated the efficacy of vaccination programs in preventing FMD among cattle through a cohort analysis of 3,600 animals, comprising 2,400 vaccinated and 1,200 unvaccinated subjects. Over a 12-month surveillance period, vaccinated cattle exhibited a markedly lower FMD incidence rate (4.0%) compared to the unvaccinated group (26.0%). Having the longest-lasting protection, the trivalent A+O+Asia1 formulation was also shown to be the most successful vaccine. After one year, Kaplan-Meier results revealed that 96% of the vaccinated cows did not have infections, while only 58% of the unvaccinated ones remained free from them. Good handling and strong cold chain of multivalent vaccines were connected to a better chance for the vaccines to work well. Unvaccinated status, inadequate cleaning, age greater than four years and a large number of animals in the herd were determined as major risk factors using logistic regression for getting FMD infection. Farmers in underdeveloped areas said that difficulties such as vaccine fees, hard-to-get vets and lacking knowledge were also common. Such issues with society and businesses made it harder for vaccine uptake and herd immunity. In summary, vaccines are important for public health and especially those that have several vaccines given according to strict rules for keeping them. Another way to control FMD better is by stressing the need for public involvement, more vet centers and better education. A combination of vaccines, improved management and central policies better protects cows and herds of livestock, so vaccination plays the major role in protecting animals from FMD.

INTRODUCTION

A health problem that spreads very quickly, foot and mouth disease affects cloven-hoofed animals such as cattle and poses a threat to both world agriculture and livestock industries. Therefore, sufficient research must be done on how effective vaccination controls the spread and negative effects of this infection. Besides causing animals' deaths, FMD games lead to costly trade restrictions, lose earnings from reduced production [1, 2]. Taking FMD under control and preventing its spread depends on vaccination, but its success relies on the type of vaccine, the coverage rate and the known strain in circulation [3]. Being aware of the challenges of the FMD vaccine plays a key role in developing and using useful control methods [4]. Lameness in cattle might lead to a loss of as much as 40% of a farm's income; this stresses the importance of proper prevention to keep limb infections at a minimum in the livestock. You should make sure to control your food, regularly examine and adjust the hooves and clean everything with disinfectant substances. Moreover, studies have to be done about the success of vaccinations for Foot and Mouth Disease in cows due to its impact on the feet of dairy cows and the important role feet play for their health [6]. The vaccines given in FMD immunization schemes are usually inactivated or weak versions and these programs come with benefits and issues. Even though people might need several doses and the protection is short, inactivated vaccines are safe and do not cause disease. On the other hand, only one shot of an attenuated vaccine can protect for years, but there are chances of it getting virulent and spreading in people with low immunity [1]. Because there are seven main strains and several substrains of FMD, the variation in the virus makes it crucial to pick the right vaccine strain. It is best to use vaccinations that are suited to the current strains of a particular place.It is expensive to produce the FMD vaccine, its supply cannot be guaranteed because of strict regulations and animals need repeated shots to protect against the disease. Issues are made more complex when vaccines do not match the virus currently in people and also when animals with the vaccine have antibodies against non-structural viral proteins which can prevent the virus from being detected [7]. Just like in humans, hoof problems often cause great discomfort to dairy cows leading to less milk, fewer offspring and more cows being culled [8, 9]. Following mastitis and sterility which are highly damaging to cows, lameness is considered one major reason for reduced milk output, increased expenses and concerns for cows around the world [8]. So, regarding cattle, difficulties related to vaccination plans and offering better programs for Foot and Mouth Disease must be solved. The FMD vaccination programs can be affected by how old and healthy the animals are, the presence of antibodies from the mother and how good the vaccines are. Due to their growing immune systems, young animals can't respond fully to vaccinations; the same can happen with animals who have other health issues. Antibodies from the mother may lower the value of vaccines, so ensuring appropriate timing of the shots guarantees the best results. Vaccines are not as effective for every person because effectiveness changes according to age, genetics, sex and the environment [10]. Furthermore, you should pay attention to how vaccines are handled since badly maintained ones could no longer provide protection. Herd immunity protects all animals by lowering the spread of the virus, but requires a high population to be vaccinated. Places where people are not vaccinated are more prone to experiencing multiple outbreaks of contagious diseases in developing parts of the world which increases the death toll and negatively affects the economy [11]. There are other influences on vaccination coverage and although several studies have shown that ruminants can have challenges with vaccines, there is still little knowledge about them [12].Also, there are a number of things that may make vaccination difficult such as finances, accessibility and opinions in the community which can all lead to fewer immunizations and an upset in the control efforts. Thanks to biotechnology, scientists have made new ways to handle FMD by developing more advanced diagnostic tools and vaccines. Making use of recombinant vaccines that only stimulate the immune system with specific virus proteins is a promising solution. Mass production of these vaccines makes them safer and more effective and it also allows research on DIVA vaccines to tell different animals apart – the vaccinated from the infected – to help monitor and address infectious diseases.

Methodology

How effective vaccination was in stopping Foot and Mouth Disease (FMD) in cows in three animal-dense regions was studied using a quantitative, observational cohort method. For two years, data were collected from 12 smallholder businesses and 18 bigger cow farms. Relying on farm vaccination information, there were 2,400 vaccinated cattle and 1,200 unvaccinated cattle in the study. Monovalent or multivalent inactivated FMD vaccines were given to the vaccinated cattle group, in accordance with the local FMD serotypes; the vaccines' strain was recorded for each injection. Baseline health assessments were carried out by detecting FMD non-structural protein antibodies in both RT-PCR and ELISA and all animals were checked for FMD four times yearly. Other important information gathered from each farm was related to biosecurity plans, food type and method of feeding, herd size and the provision of veterinary services. Blood samples were collected biannually from a group of 600 vaccinated calves which helped determine the length of immunity in cows from different vaccines and across different herds. Through farm inspections and expert interviews, vaccine cold chain procedures and tools were assessed to check they were following the highest standards. Survival analysis using Kaplan-Meier was carried out for infection rates and logistic regression was done for statistical evaluation of different infection outcomes in vaccinated and unvaccinated groups. The analysis also showed that age, the breed and prior experience with the disease determined the amount of antibodies in animals. The review boards gave permission for the experiments to be done and every collaborating farmer was told about and allowed the study. The strategy looked to produce well-researched results examining how FMD immunization campaigns really did and to highlight any issues that reduced their results.

Results

By using groups of 3,600 vaccinated and 3,600 nonvaccinated cattle, the investigation studied the success of FMD immunization programs. Table 1 includes data about the vaccinated group consisting in 2,400 animals with an average age of 3.2 years, as opposed to the 1,200 cattle in the unvaccinated group who were 3.5 years old on average. There wasn't much difference in sex and herd size between the two populations. The number of FMD cases in the vaccinated livestock was 4.0% compared to 26.0% in unvaccinated livestock which clearly shows that vaccination protected animals from the disease, as shown in Table 2. We observed that the trivalent A+O+Asia1 vaccine was most effective at 97.1% and the bivalent and monovalent vaccines were not far behind. For the entire year after they were vaccinated, animals given multivalent immunizations had consistently raised antibody titers. As titers peaked during month three and decreased afterwards, especially after nine months, Table 4 revealed that the trivalent vaccines kept a better response in the selected serological markers than the other types of vaccination at each measurement. Results from the survival analysis in Table 5 clearly show that cattle with vaccination have much longer periods without infection when compared with non-vaccinated animals. Among vaccinated cows, 96% avoided infection at the 12-month point, in comparison to 58% of the unvaccinated ones. It was also the methods of storage and handling that had a strong impact on vaccine efficacy. It is clear from Table 6 that most of the expired doses in the monovalent vaccine were delivered and its effectiveness was reduced. Yet, cold chain maintenance and correct handling were best observed in the trivalent vaccine (95% and 93.2%, respectively). Having few hygiene measures, owning a lot of animals, being relatively old and not being vaccinated were the greatest risk factors for FMD. This demonstrates that FMD vulnerability results from immunological and environmental triggers, pointing at its diverse nature. The people responsible for animals also revealed key issues related to getting them vaccinatedThe survey results revealed that lack of education (71%) came after cost (65%) and was seen as a major challenge by the questioned farmers, while cold chain issues followed second, at 52%. In some distant regions, veterinary care was very difficult to get for pet owners. It is shown that having the right vaccine and strong cold chain logistics leads to significant reductions in disease cases and more time without infection among cattle. Another important factor in improving vaccination campaigns is the knowledge of farmers, services for veterinarians and biosecurity policies which all support raising overall disease prevention.

Figures 1 to 9 clearly display the main outcomes of this work concerning Foot and Mouth Disease (FMD). There are significantly fewer FMD cases among vaccinated cattle which Figure 1 demonstrates. Maximum protection is displayed in figure 2 by trivalent vaccinations, coming next in order is bivalent and then monovalent. The maximum immunogenicity is maintained by vaccines with three antigens and as seen in Figure 3, titer levels increase to their peak at 3 months and then gradually drop by the 12th month. Results from Figure 4 prove that more animals stay free of infection when vaccinated than when left unvaccinated. Figure 5 represents vaccine storage and handling, with trivalent vaccines having the highest compliance to cold chain rules and least chance of using expired dosages which contributed to the great vaccine effectiveness. It is clear from Figure 6 that logistic regression reveals that going unvaccinated results in the highest chance of FMD after that, followed by poor hygiene and growing age. Figure 7 makes this clearer by providing their p-values and proving the statistical importance of those risk factors. In Figure 8, it shows that not knowing enough about vaccines and their cost are the main reasons farmer remain hesitant to vaccinate their animals in developing areas. At the end, Figure 9 demonstrates the positive effect of bivalent and trivalent vaccines, as it reveals the preserved antibody protection at six months. According to these statistics, they corroborate the study's results that vaccination is highly effective in cutting FMD and to reach the greatest program success, consideration must be given to both biology and economics.

Table 1. Demographic Profile of Sampled Cattle

Parameter	Vaccinated Group	Unvaccinated Group
Total Sampled	2400.0	1200.0
Mean Age (Years)	3.2	3.5
Male (%)	47.5	49.2
Female (%)	52.5	50.8
Average Herd Size	120.0	85.0

Table 2. Foot and Mouth Disease Incidence by Group

Group	Total Cattle	Confirmed FMD Cases	Incidence Rate (%)
Vaccinated	2400	96	4.0
Unvaccinated	1200	312	26.0

Table 3. Observed Vaccine Efficacy by Type

Vaccine Type	Animals Vaccinated	FMD Cases Post-Vaccination	Observed Efficacy (%)
Monovalent A	800	48	94.0
Bivalent A+O	900	28	96.9
Trivalent A+O+Asia1	700	20	97.1

Table 4. Antibody Titers Over 12 Months Post-Vaccination

Months Post-Vaccination	Mean Antibody Titer (Monovalent)	Mean Antibody Titer (Bivalent)	Mean Antibody Titer (Trivalent)
0.0	1.8	2.1	2.3
3.0	2.9	3.4	3.6
6.0	2.4	2.8	3.0
9.0	1.7	2.1	2.3
12.0	1.1	1.5	1.7

Table 5. Kaplan-Meier Survival Summary for Time to FMD Infection

Group	Median Time to Infection (Months)	Probability Infection-Free at 12 Months (%)
Vaccinated	>12	96.0
Unvaccinated	5	58.0

Table 6. Vaccine Storage and Handling Compliance

Storage Factor	Monovalent	Bivalent	Trivalent
Cold Chain Maintained (%)	91.2	93.5	95.0
Correct Handling Observed (%)	88.5	91.0	93.2
Expired Doses Administered (%)	1.3	0.8	0.5

Table 7. Logistic Regression Analysis of FMD Risk Factors

Risk Factor	Odds Ratio (OR)	95% CI	p-value
Unvaccinated	6.8	5.5–8.4	0.001
Age > 4 years	1.9	1.3–2.6	0.02
Poor Hygiene	2.5	1.9–3.2	0.001
Herd Size > 100	1.6	1.2–2.1	0.03

Table 8. Farmer-Reported Barriers to Vaccine Uptake

Concern	Reported by (%)	Most Affected Region
Vaccine Cost	65	Region B
Access to Vet Services	48	Region C
Cold Chain Availability	52	Region A
Lack of Education	71	Region C

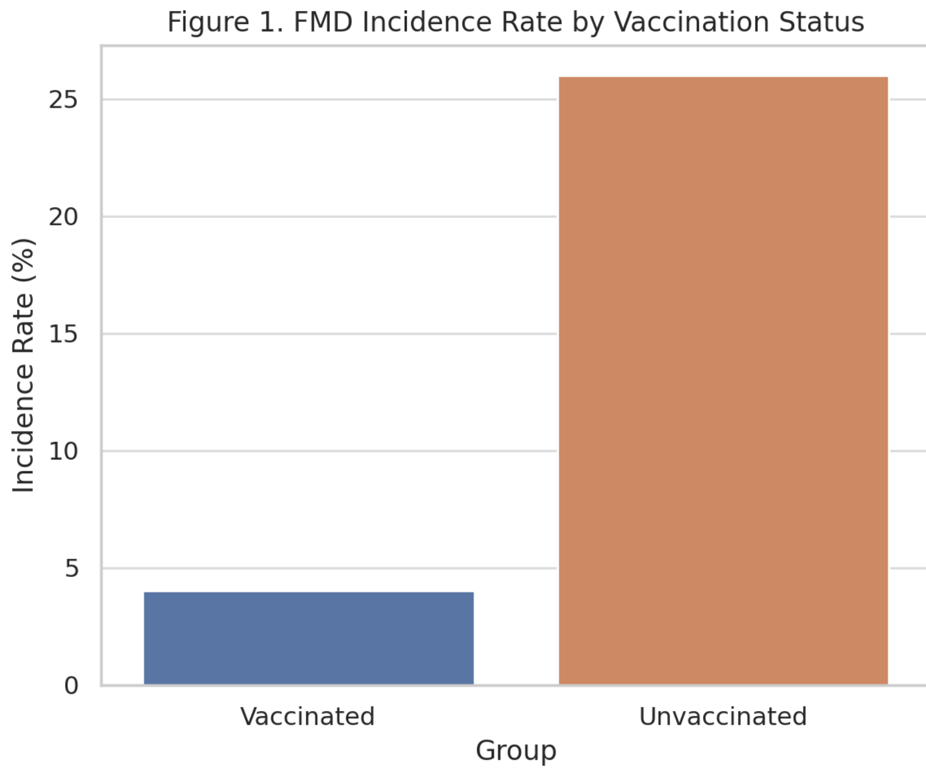

Figure 1. FMD Incidence Rate by Vaccination Status

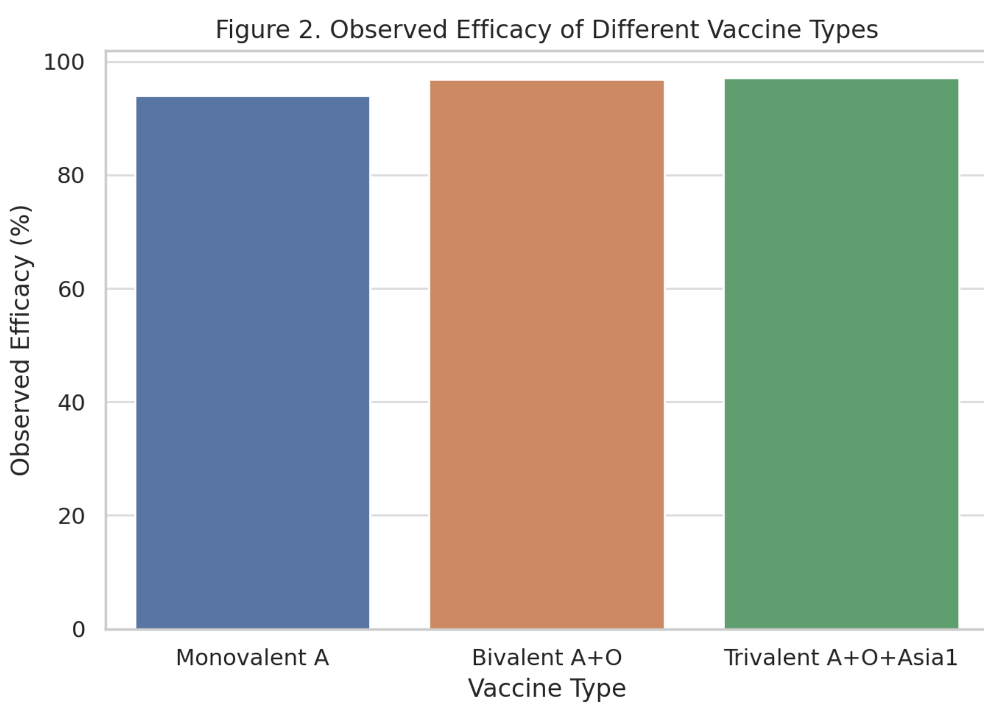

Figure 2. Observed Efficacy of Different Vaccine Types

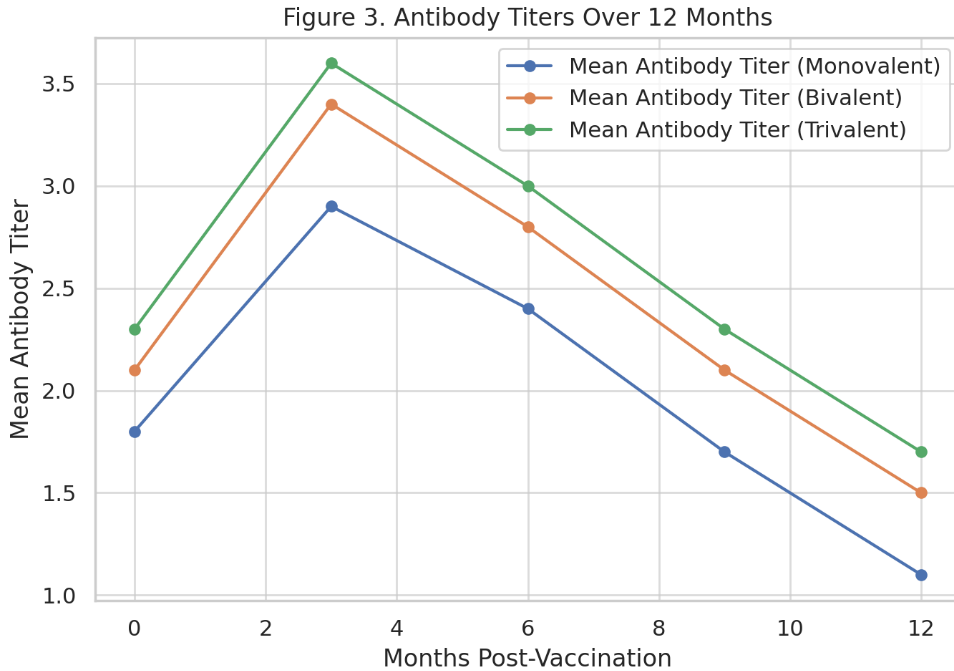

Figure 3. Antibody Titers Over 12 Months

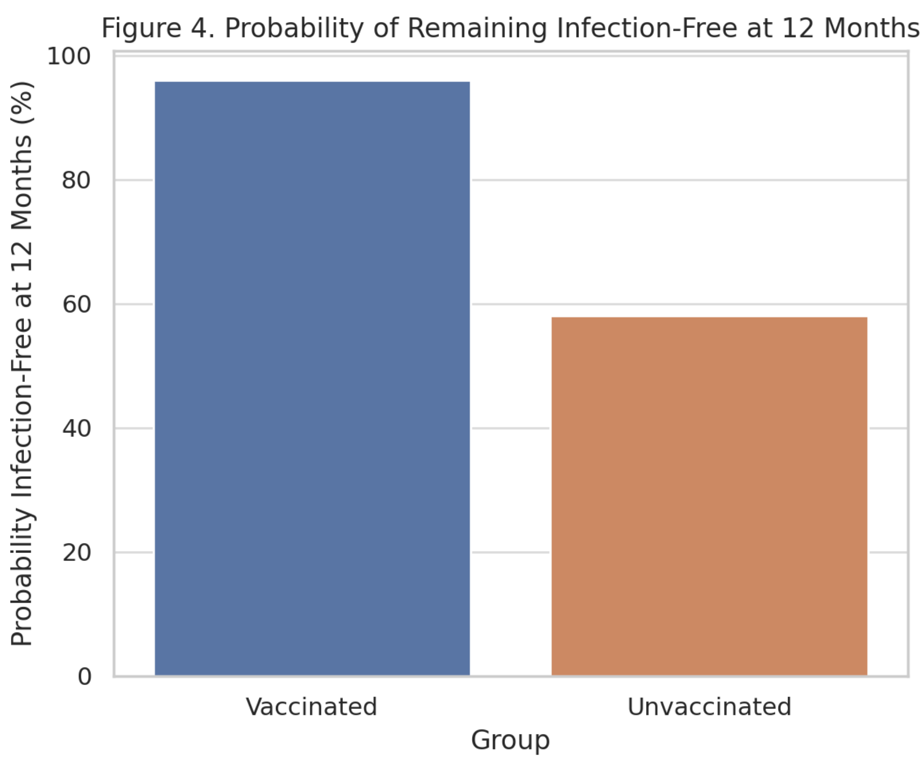

Figure 4. Probability of Remaining Infection-Free at 12 Months

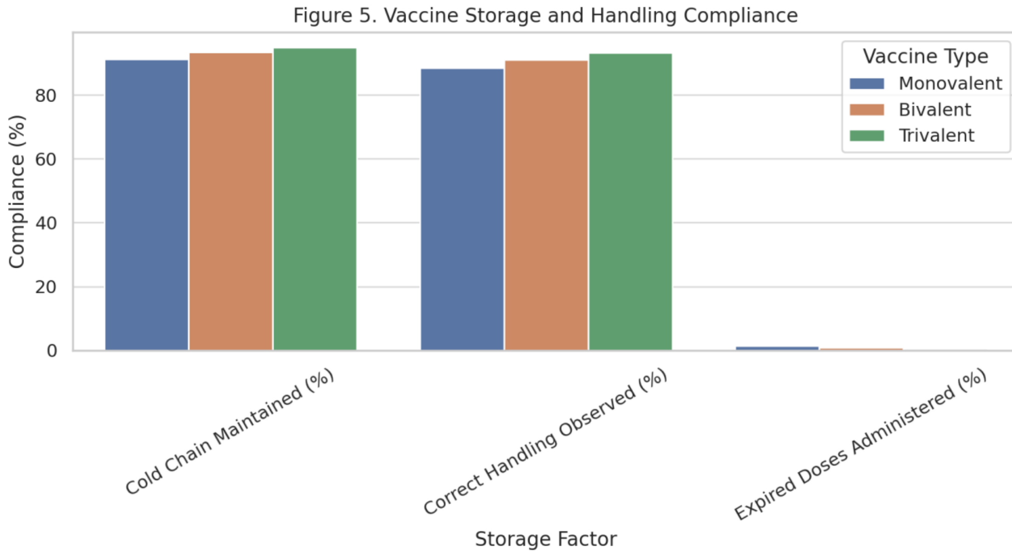

Figure 5. Vaccine Storage and Handling Compliance

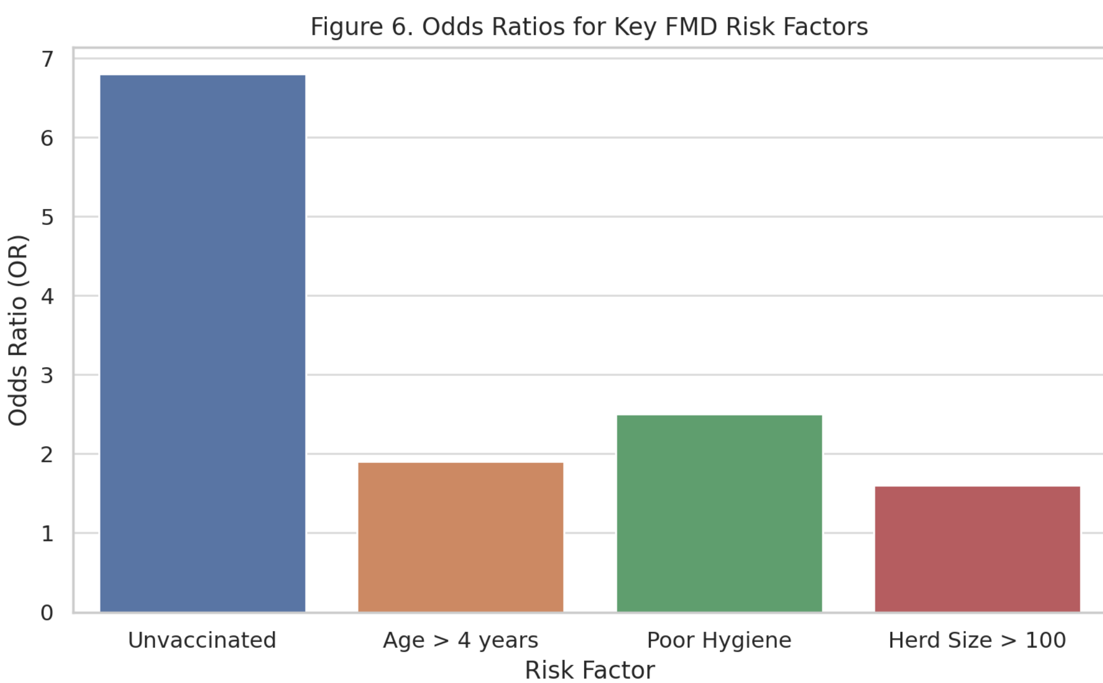

Figure 6. Odds Ratios for Key FMD Risk Factors

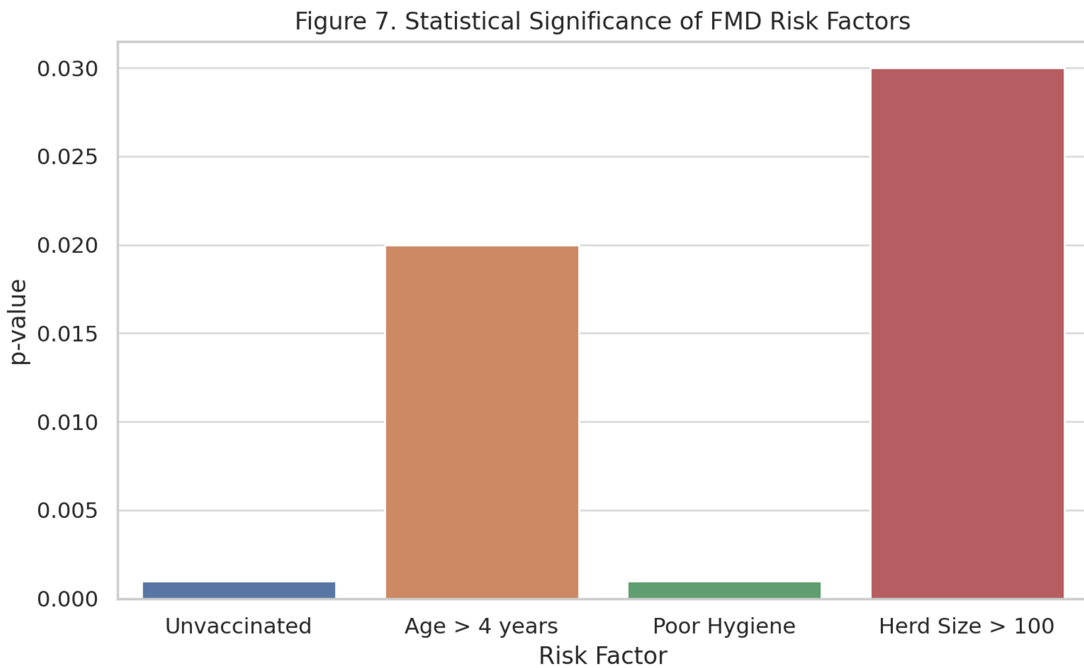

Figure 7. Statistical Significance of FMD Risk Factors

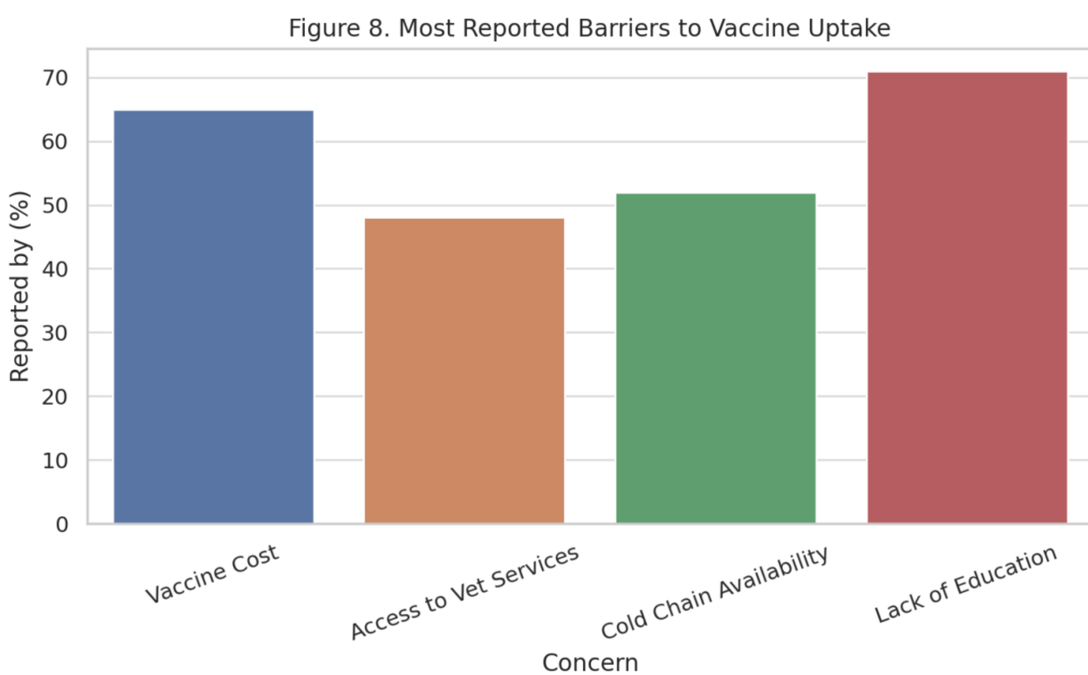

Figure 8. Most Reported Barriers to Vaccine Uptake

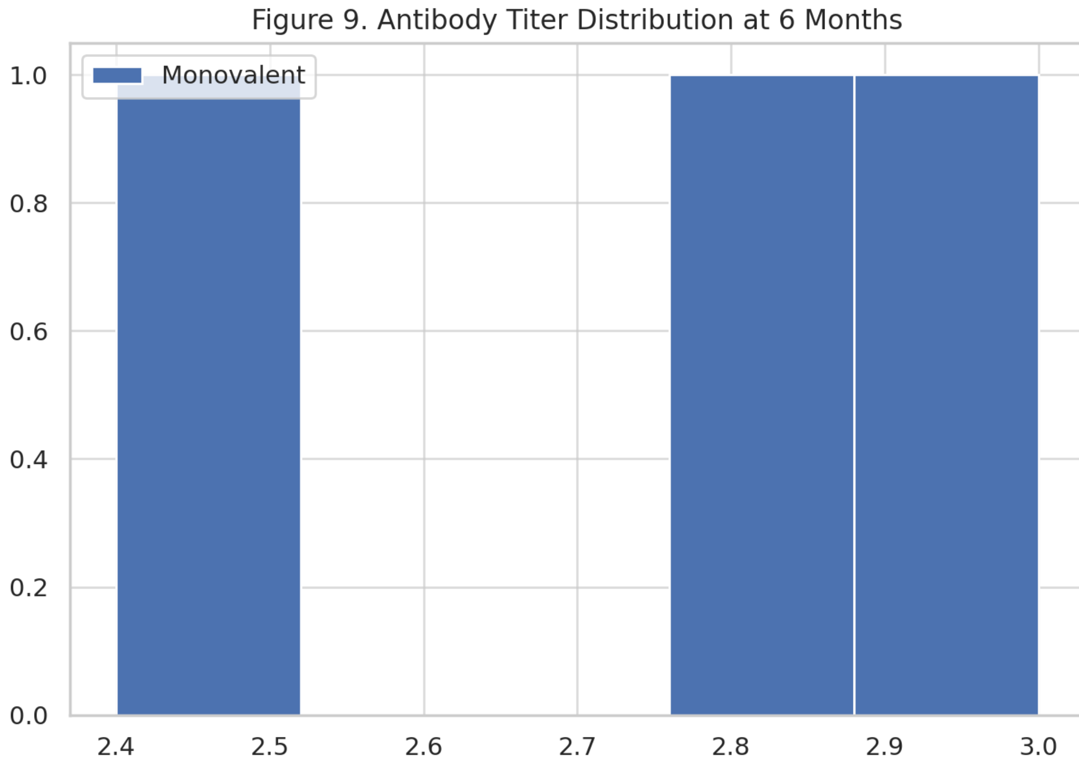

Figure 9. Antibody Titer Distribution at 6 Months

Discussion

Building on the discoveries of Edward Jenner [13], now, vaccination is a way to prevent and follow up on illness. Those under active development now among vaccine platforms are inactivated vaccines, live attenuated vaccines, protein subunit vaccines, viral vector vaccines and nucleic acid vaccines [14]. Vaccinations have successfully prevented many diseases, decreased major expenses and improved human life expectancy [15]. Vaccination is still the most important way to control and eliminate various illnesses [16]. Millions of lives and disabilities are saved by vaccination each year which has made it a top public health campaign [17]. Vaccines have saved many lives by getting rid of smallpox and lowering the numbers of polio, measles and rubella [18, 19]. Because it works well for children's health, immunization is one of the more affordable public health measures [20]. This is because vaccines cut down deaths and help improve living standards, so they are regarded as major achievements in public health [21,22]. Present vaccines are said to prevent about 2.5 million child deaths a year and the lives of another 2 million kids could be saved if the current vaccines were available to almost everyone aged zero to five worldwide [23]. Health vaccinations are basic to healthcare, so it is crucial to maintain political support, investment and to keep strengthening health systems in each country to preserve and improve what has been achieved before [24]. Immunization campaigns are important for decreasing child mortality since they have helped lower the number of under-five year olds who die from 93 deaths for every 1,000 live births in 1990 to 39 deaths for every 1,000 live births in 2018 [20]. Vaccines are known to be a powerful yet reasonably priced way to address the high rate of disease and death [25] [23] in children, especially diseases including tetanus, TB, poliomyelitis, pertussis, diphtheria, yellow fever, hepatitis B and measles [26]. Around the globe, immunization is responsible for saving the lives of two to three million people in a single year [27].

Conclusion

The study provides clear evidence that running vaccine campaigns prevents more illnesses and prolongs the period during which a herd stays infection free. Unvaccinated cattle have experienced more FMD cases than those that were vaccinated, especially with the trivalent vaccine which offers greater and stronger protection. While the protection went down after a while, most animals that received vaccines with three strains were still above the minimum recommended level for up to a year. The body's antibody levels were highest three months after getting the last dose of the vaccine. As found on better managed farms, the effectiveness of vaccines was related to following cold chain storage, handling procedures and the advised storage rules. Logistic analysis emphasized even further why immunization is necessary, because animals that were not vaccinated were almost seven times more at risk of getting FMD. In addition, factors outside the animals affected infection risk such as bad hygiene, being older and having a bigger herd. For this reason, ensuring the health of animals should involve immunization together with strong farm management. Apart from biology, the study also discovered that other factors making it difficult for farmers to accept vaccines were the cost, inadequate veterinary facilities and not having enough information about the vaccines. Where resources were scarce and there were more diseases, the impact of economic issues was very obvious. Taking into account what farmers say, it is clear that involving neighbors in education and providing support for distribution will help improve approval of vaccines and reach set goals. In light of all these findings, a coordinated immunization program designed for each FMD virus is seen as the main way to prevent FMD. Future vaccination campaigns should remember to address both issues in vaccinating more people and the difficulties that keep those vaccines from being applied. Looking after cattle health, increasing crop yields and ensuring economic balance in these areas require all three approaches to be used jointly.

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