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Infection Prevention Elements *Streptococcus suis* using One Health System Health Zone 2, Thailand

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Abstract

This study assesses the effectiveness of the One Health System in preventing *Streptococcus suis* infections in Health Zone 2. Utilizing an exploratory sequential mixed-method approach, the research integrates in-depth interviews with affected individuals and specialists with a survey of 375 disease control practitioners. Analysis revealed a comprehensive set of factors critical to infection prevention, broadly categorized under human, swine, and environmental domains. Significant human-related factors include hygiene practices among swine workers and the influence of behaviors and personal beliefs on disease risk. In the swine domain, management practices before slaughter and during raising significantly impact safety measures against *Streptococcus suis*. Environmental factors such as sanitation and local regulations also play crucial roles in disease prevention. These findings suggest that targeted improvements across these domains can considerably enhance prevention strategies. The study underscores the need for a dynamic, adaptable prevention model and proposes longitudinal research to further investigate these strategies across more diverse geographic areas.

Keywords**:** *Prevention of infection; Streptococcus suis; One Health System; swine*

1. Introduction

The current situation shows the rapid development of medical science and public health alongside material prosperity. However, new infectious diseases, termed emerging infectious diseases, have emerged. These include diseases that had previously spread and subsided, and now have returned (Bureau of Emerging Infectious Diseases, 2011). It has been found that more than 75 percent of these diseases are zoonotic diseases, such as coronavirus disease 2019 (COVID-19), a newly emerging disease believed to be transmitted from animals. The outbreak started in Wuhan, China in December 2019 and led to a widespread global pandemic (World Health Organization Thailand, 2022). *Streptococcus suis* (*S. suis*), also known as "Hearing-loss fever" is caused by the bacterium *Streptococcus suis*. It can be found in certain mammals and birds, with swine serving as a significant host animal. Infected swine usually does not show symptoms. This bacterium can be transmitted to humans through various means, including cuts, abrasions, conjunctiva, or direct inhalation of infected droplets, and the consumption of undercooked pork. The latter is the most common cause of infection in humans (World Health Organization, 2021).

The infectious disease *Streptococcus suis* was first reported in humans in Denmark. The disease's first outbreak was identified in China

between 1998 and 1999. *Streptococcus suis* infection is most prevalent in Southeast Asia, with Thailand ranking third globally. The disease was first reported in 1987 with an outbreak occurring in Phayao Province. In May 2007, there were 33 patients, with 3 fatalities. This trend has continued over the past five years, with an increase in the incidence of disease. Between 2017 and 2021, there were 318, 317, 377, 344, and 586 cases respectively, according to various sources (Bureau of Emerging Infectious Diseases, 2011; Hughes et al., 2019; Bureau of Epidemiology, 2022; Chaknum, 2008) In Health Zone 2, comprising the provinces of Phitsanulok, Uttaradit, Sukhothai, Tak, and Phetchabun, a total of 132 patients were reported, with a morbidity rate of 3.73 per 100,000 people and 4 deaths. The mortality rate was 0.11 per 100,000 people. The mortality rate was 3.03 percent relative to the morbidity rate. Health Zone 2 was found to have a higher rate than the national average. The most affected age group is those aged 65 years and older. The most commonly affected occupation is agriculture, consistent with the national trend (Bureau of Epidemiology, 2022).

Disease-causing factors can be categorized into 3 aspects based on epidemiological principles: 1) Agent: *Streptococcus suis* serotypes 1 and 2 are the most common and severe agents causing disease in swine. For humans, serotype 2 is the most common. 2) Environmental: swine farms, slaughterhouses, and butchers in markets are particularly significant risk factors. Regarding temperature and weather, it was found that farms with higher temperatures tend to have more cases of infected swine than those with lower temperatures. Cultural traditions contribute to a higher number of patients during the Songkran festival and the agricultural season. 3) Host: The disease is predominantly caused by the consumption of raw or undercooked pork, especially in the northern region. In occupations related to swine, a higher infection rate was found in males than in females. Working-age individuals and the elderly are the most commonly affected groups. Individuals who regularly consume alcoholic beverages and those with chronic diseases are at increased risk of infection (Huong et al, 2016; Yongkiettrakul et al., 2019; Noppon et al., 2014; Chankitkan, 2019; Prasertsang, & Cheveerach, 2019; Zou et al., 2018; Takeuchi et al., 2017)

In the past, surveillance, control, and prevention of infection in Thailand encountered relatively few, attributed to limitations in laboratory testing. Doctors remain unfamiliar familiar with the disease. Systematic problems have been identified in the operations of disease control and prevention. Disease outbreaks are likely to increase. There is a lack of awareness regarding laboratory testing. Disease reporting is still only found in provinces that have experienced incidences of the disease (Chaknum, 2008). The referral system is not appropriate and timely for death and disability. Preparing for and responding to disease threats poses a significant challenge. Relying on knowledge of disease epidemiology, along with new medical technology, is essential to reduce disease incidence and improve survival rates. This approach aligns with the concept of the One Health System.

One Health System has the perspective that if any illness occurs, it may be caused by one of the other's 3 components: humans, animals, and the environment. These issues must be resolved quickly to prevent imbalance and widespread losses. leading to widespread losses (Supanitayanon, 2014; Frankson et al., 2016; World Health Organization, 2019). An important goal is the strengthening of integration across all professional sectors and levels to promote good health. An important goal is the strengthening of integration across all professional sectors and levels to promote good health (Somnathaweechai et al., 2014). In Thailand, the One Health System is incorporated into the Thailand national strategic plan for emerging infectious disease (2013 – 2016) and Thailand national strategic plan for emerging infectious disease (2017 – 2021). It is supported by the Thai One Health network coordinating unit for One Health working group. The vision is for Thailand to prevent and control emerging infectious diseases systematically, efficient, in a timely manner, and in accordance with international standard through integrated management, knowledge management, and participation from all sectors. This includes 6 strategies, with strategy 2 focusing on the development and strengthening of surveillance, prevention, treatment, and control systems for emerging infectious diseases under the One Health concept (Bureau of Emerging Communicable Diseases, 2016). There are activities to integrate and create cooperation among all sectors, enhancing the efficiency of disease surveillance, prevention, investigation, and control in humans, pets, wildlife, and ecosystems. This

effort includes augmenting the capacity for laboratory testing and networks, as well as developing systems for diagnosis, treatment, and control of emerging infectious diseases (Coordinating Unit for One Health, 2023).

The concept of the One Health System, as mentioned, has been widely used internationally., For example, the study "Tick and tick-borne diseases: One Health perspective" found that the importance of a One Health Systems approach to tick-borne diseases should be emphasized, considering the cooperation between doctors and veterinarians in managing these diseases. Including other diseases that are transmitted from animals to humans (Dantas-Torres et al., 2012) or a study in Thailand on "Using the One Health concept as a tool to reduce the number of patients with *Streptococcus suis* in people in Chiang Mai Province" found that although swine are important carriers of *Streptococcus suis* and the infection can spread to people through the slaughter process, consumption behavior is an important factor that affects *Streptococcus suis* in humans (Rojanasathien, 2017). The researchers are therefore interested in studying the components of infection prevention *Streptococcus suis* using the One Health System concept in the context of Health Zone 2 to develop an effective and sustainable infection prevention model.

2. Objectives

1) To assess the current status of *Streptococcus suis* infection prevention within Health Zone 2 by employing the One Health System.

2) To identify and analyze the specific components contributing to the prevention of *Streptococcus suis* infection using the One Health System within Health Zone 2.

3. Materials and methods

A study is being conducted on the prevention of *Streptococcus suis* infection in Health Zone 2 using a One Health System approach. The study will use a mixed-methods research design, specifically an exploratory sequential design, involves the following steps. A qualitative study will be conducted using in-depth interviews and a purposive sampling method in homogenous groups until data saturation, as follows This involves five cases with a history of *Streptococcus suis* infection or their relatives and 12 experts from relevant fields as identified in the One Health System. The instrument used was a semi-structured interview. The interview format is divided into 2 sets: the first set of questions is for people with a history of infection or their relatives. It covers issues such as 1) Disease awareness 2) causative factors 3) prevention before infection and 4) prevention after infection. A second set of questions for experts covers issues such as: 1) preventing infection in the past, 2) preventing infection in the present, 3) factors for preventing infection using One health system, and 4) roles in preventing infection. Content validity was checked by three experts (medical, veterinary, and academic). The researcher collected and analyzed the data using thematic analysis. The quality of data will be ensured by using triangulation, a theoretical aspect, by comparing it with documents and literature that should align with the data. Relocating truths indicates that the information is correct and complete (Major, & Savin-Baden, 2010). The study used Exploratory Factor Analysis (EFA) among workers involved in the control and prevention of infectious diseases in humans. The study area includes Phitsanulok, Uttaradit, Sukhothai, Tak, and Phetchabun provinces. The study population was 757 people. The sample size was determined by the rule of thumb, a statistical technique involving multivariate analysis, requiring at least 300 cases, to prevent data loss. If the sample did not fully answer the questionnaire, the researcher collected an additional 25 percent, resulting in a calculated sample size of 375 subjects. Multi-step sampling was conducted as follows: 1) Cluster or Area Sampling involved selecting three provinces at random from health zone 2. Using simple random sampling by lottery drawing without replacement, the provinces of Phitsanulok, Sukhothai, and Uttaradit were chosen. 2) The selection in step 1 followed the principle of proportional to size (PPS) 3) Stratified sampling, which involved dividing the population into groups of workers at the provincial, district, and sub-district levels and 4) Simple random sampling, using a computer to generate random numbers by inputting commands between the numbers 1 and N to get the desired number of random selections.

The data collection tools included a questionnaire created by the researcher, based on textbooks and related research documents, to cover the content and results of the in-depth interviews. The questionnaire was divided into 2 parts: 1) A

form recording the personal characteristics of respondents, including gender, age, marital status, position, and work experience, and 2) Factors preventing against infection *Streptococcus suis* using One Health System approach, with a total of 70 questionnaires, divided into 3 issues: human, swine, and the environment. The answer format is a 5-level rating scale, divided into 3 levels of prevention: high, medium, and low. The quality of the tool was checked by 3 experts using the content validity index (CVI). The evaluation results showed that the S-CVI value was 1.0 and, for reliability, testing on 30 people using the method of calculating Cronbach's alpha coefficients yielded the following values: 1) Prevention of *Streptococcus suis* infections in humans: 0.94, 2) Prevention of *Streptococcus suis* infections in swine: 0.88, 3) Prevention of *Streptococcus suis* in the environment: 0.94, and 4) Overall prevention of *Streptococcus suis* infections: 0.97, with an acceptable reliability value of greater than or equal to 0.80 (Burns, & Grove, 2001). Data were analyzed using descriptive statistics, including frequency, percentage, standard deviation, and exploratory factor analysis (EFA). Then, data was collected using questionnaires. At the provincial and district levels, the researcher collected the data personally. As for the sub-district level, the person responsible for the district level will collect the data for the researcher. Ethical approval for this study was obtained from the Ethical Committee of Naresuan University (IRB No. P2-0135/2564 COA No.354/2021).

4. Results

4.1 In-depth interviews result

From in-depth interviews involving five cases of individuals with a history of *Streptococcus suis* infection or relatives and 12 experts in each field, according to the components of the One Health System, new issues were identified as follows:

4.1.1 The history of patients or relatives: Target Group's Perspectives:

1) Factors for prevention of infection *Streptococcus suis* on the human side include not being aware of the dangers of the disease. "*I think it is far away for me and my family*." "*Many people ate it, other people weren't sick, I'm the only one who's sick.*" "*They eat normally, it's like there are a lot of people eating, I don't see a problem."*

2) Factors for preventing *Streptococcus suis* infection in swine include observing swine before slaughtering and separating them. This process takes place after the swine is unloaded from the transport truck and waiting for slaughter using observational methods. *"We will know it will be red. People at the slaughterhouse and the carcass inspector will know." "Symptoms of depression are easy to see. If these swine have a fever, it will be difficult to breathe. It will sit in the cat position."* Even though the swine were known to be sick, there were no regulations or rules prohibiting them from being euthanized. It is an issue of measures, rules, and regulations regarding swine slaughtering. *"There are no problems, no exceptions. It's just that we have to slaughter it later. You have to slaughter the last one." "At the slaughterhouse. He did not deny that the swine was sick. Swine have disease and sick swine can be slaughtered. But you must slaughter it later, and then the factory is cleaned because the department's regulations are like this according to standards."*

4.1.2 Experts from relevant fields as identified in the One Health System: Expert Insights and Recommendations

1) Factors for prevention of infection *Streptococcus suis* on the human side include not being aware of the dangers of the disease. *"It's like eating grilled pork, we use chopsticks to hold the pork to grill and then use the same to hold the pork. The pork is cooked but the chopsticks aren't. People didn't think they would get infected."*

2) *Streptococcus suis* infection prevention factors on the environment include measures, rules, and regulations for large and small farms, slaughterhouses, and markets. "*There must be more comprehensive measures for both farms, slaughterhouses, and markets, and add those that are raised in the home as well. This one requires special care."* However, most of the factors involved are human factors. *"This disease mainly depends on people. Especially the behavior of people." "It mainly depends on the people. If we can protect people, swine, and the environment, we can control it."*

The researchers then combined the results with a review of related literature and research and conducted a study on the *Streptococcus suis* infection prevention components in Phase 2. The results of the study are as follows:

4.2 Questionnaire result analysis

The researcher utilized a questionnaire to gather data from a sample group, specifically individuals working in disease control within Health Zone 2. Out of 375 people, 375 sets of questionnaires were returned fully completed, yielding a response rate of 100%. Subsequently, the data was analyzed, revealing the following results.

4.2.1 The personal characteristics of respondents

The sample group consisted of 375 individuals, with females comprising 56.8 percent. The majority, 39.5 percent, were aged between 22 and 34 years. The average age was 38.4 years. The most common marital status was married, at 47.7 percent. The majority of positions were in public health academics, accounting for 76.5 percent. Those working in disease control primarily had 1 to 10 years of experience, representing 58.4 percent.

4.2.2 Prevention level

Infection prevention factors for *Streptococcus suis* showed that all 70 factors were considered highly effective in prevention. The factor emphasizing the immediate separation of a sick swine from the herd upon discovery was rated the highest in terms of importance ($\bar{X}$=4.92, S.D.=0.34). Conversely, the factor considered least significant was the proximity of a house to a main road, suggesting ease of germ transmission into the home ($\bar{X}$=4.24, S.D.=0.90).

4.2.3 Comprehensive Factor Analysis for Streptococcus Suis Infection Prevention Strategies

Utilizing the One Health System approach, the researcher embarked on an exploratory factor analysis to categorize prevention factors into three main issues: Human (factors 2, 3, 5, 11, 30, 31, 32, 33, 34, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 61, 62, 63, 64, 65, and 70), Swine (factors 1, 6, 7, 8, 9, 18, 19, 20, 21, 22, 23, 28, 35, 39, and 60), and Environmental (factors 4, 10, 12, 13, 14, 15, 16, 17, 24, 25, 26, 27, 29, 36, 37, 38, 40, 66, 67, 68, and 69). The resulting factor categorizations highlighted these divisions clearly.

The analysis proceeded with calculating the correlation coefficients between all variables using Pearson's Product Moment Correlation formula, expressed as a correlation matrix. Each variable significantly correlated at the 0.05 level. The suitability of the data for factor analysis was affirmed by high Kaiser-Meyer-Olkin (KMO) statistics for humans, swine, and the environment, with values of 0.91, 0.90, and 0.92, respectively. Bartlett's test of sphericity further confirmed the non-identity of the correlation matrices, endorsing the data's appropriateness for factor analysis.

Subsequent factor extraction used Principal Component Analysis (PCA), with further refinement achieved through factor rotation using the Varimax method. This process identified significant factors with eigenvalues exceeding 1.0, resulting in six components for the human aspect, two for swine, and four for the environmental aspect, detailed in Table 1.

The interpretation of data across human, swine, and environmental dimensions revealed critical factors contributing to the prevention of *Streptococcus suis* infections. Each factor required an eigenvalue greater than or equal to 1.0 and significant contributions from three or more variables with a weight of 0.40 or more.

In the human aspect, four of six components were significant: Factor 1, 'Hygiene of swine workers', included 21 variables and a variance up to 46.639%, emphasizing its importance. Factor 2, 'Behaviors and beliefs that may cause disease', comprised four variables, capturing cultural influences on disease spread. Factor 3, 'Increasing/reducing a person's risk of infection', and Factor 4, 'Personal factors conducive to disease', addressed individual risk factors and personal health interactions, respectively, contributing to a cumulative variance of 62.80%.

For swine, Factor 1, 'Management of swine before butchering and evisceration of swine meat', detailed seven variables focused on disease-free meat production practices, with eigenvalues up to 6.162 and a significant variance of 41.078%. Factor 2, 'Raising swine to be safe from *Streptococcus suis* infection', included eight variables focusing on preventative measures in farming, accounting for a cumulative variance of 50.80%.

The environmental dimension yielded four significant factors: Factor 1, 'Sanitation', with 11 variables, showed the highest environmental variance at 45.669%, highlighting essential hygiene practices. Factor 2, 'Rules, regulations, and laws for preventing *Streptococcus suis*', Factor 3, 'Reducing disease-causing factors', and Factor 4, 'Local

culture that is a risk factor for *Streptococcus suis* infection', each addressed regulatory compliance, direct environmental risks, and cultural risk factors, respectively, with a cumulative variance of 64.97%. These comprehensive factors, detailed in Table 2, illustrate robust preventive measures across dimensions, providing a framework for targeted strategies against *Streptococcus suis* infections.

Table 1 Initial eigenvalues, percentage of variance, and Cumulative percentage of variance in each component of preventive factors against *Streptococcus suis* in humans, swine, and the environment (n=375)

Component	Initial Eigenvalues	% of Variance	Cumulative %
Human			
1	15.857	46.639	46.639
2	2.801	8.237	54.876
3	1.457	4.285	59.161
4	1.238	3.643	62.804
5	1.091	3.210	66.014
6	1.037	3.051	69.065
Swine			
1	15.857	46.639	46.639
2	2.801	8.237	54.876
Environment			
1	15.857	46.639	46.639
2	2.801	8.237	54.876
3	1.457	4.285	59.161
4	1.238	3.643	62.804

Table 2 Mean, S.D., Levels of preventive factors, and Weighting factors of prevention *Streptococcus suis* in 3 aspects of One Health System (n=375)

No.	Factors	$\bar{X}$	S.D.	Component			
				1	2	3	4
Human aspect							
52	Buyers should purchase food made from cooked pork only.	4.86	0.41	0.837			
51	After finishing cooking, utensils, knives, and cutting boards must be cleaned and stored in a dry place.	4.84	0.43	0.827			
42	Pork sellers must practice personal hygiene.	4.82	0.45	0.822			
50	Cooking pork to eat must be done only until cooked.	4.85	0.40	0.821			
33	While slaughtering and butchering swine, one must wear an apron, hat, hairnet, and boots.	4.87	0.37	0.794			
41	Pork sellers must wear clean clothing and must have protective equipment such as hats or hairnets and aprons.	4.80	0.46	0.775			
34	After killing and dissecting the swine, they bathe. Wash your body thoroughly every time.	4.87	0.37	0.768			
53	If you are unsure about pork meat that has been cooked, it should be heat-treated again, such as swine heads.	4.82	0.47	0.746			
44	Buyers should choose to purchase pork from a swine butcher that has passed the standards for places selling clean meat (clean cutting board).	4.81	0.46	0.744			
46	Cooks who have wounds in areas that need to come into contact with pork must cover the wound completely.	4.81	0.50	0.721			
49	Cooks should not taste raw or undercooked pork.	4.84	0.41	0.721			

Table 2 Cont.

No.	Factors	$\bar{X}$	S.D.	Component			
				1	2	3	4
30	Those who slaughter and butcher swine must undergo an annual health examination.	4.83	0.42	0.715			
47	Cooks should wash and clean pork with clean water before using it for cooking every time.	4.80	0.46	0.708			
48	When preparing food, knives and cutting boards should be separated for pork, vegetables, and fruits. If they cannot be separated, vegetables and fruits should be prepared first.	4.82	0.46	0.704			
31	Those who slaughter and butcher swine should be in good health.	4.79	0.49	0.672			
45	Buyers should not choose to buy pork from hawkers, don't know the origin of the production source, or have abnormally cheap prices.	4.71	0.56	0.672			
43	Pork sellers who have wounds in areas that come into contact with pork must cover the wound completely.	4.80	0.54	0.651			
54	You should avoid eating food prepared from pork at parties or restaurants where you are not sure whether it is cooked or not.	4.75	0.56	0.631			
11	Raiders should wear gloves whenever handling swine that has died due to illness or unknown causes.	4.89	0.37	0.583			
70	People should have their physical health checked annually.	4.82	0.47	0.574			
32	People who have wounds or abrasions on their bodies, especially on their hands, should not kill and butcher swine.	4.79	0.48	0.527			
58	The belief that eating uncooked red food, such as raw minced pork with blood, will be auspicious is considered a false belief.	4.42	1.15		0.846		
59	Showing leadership or masculinity has nothing to do with eating raw or undercooked food.	4.57	0.97		0.766		
57	Taking antibiotics before eating raw or undercooked pork cannot prevent *Streptococcus suis* infection.	4.35	1.22		0.755		
55	If you wish to eat food from raw pork such as fermented pork or raw pork sausage, you should choose products that have been irradiated to a level that kills microorganisms only.	4.46	0.96		0.518		
02	Swine birth attendants should wear gloves every time while deliver piglets.	4.90	0.35			0.784	
03	Swine birth attendants should wear a mask every time while deliver piglets.	4.80	0.55			0.728	
05	After the process of giving birth to piglets, you must take a shower to cleanse your body every time.	4.89	0.36			0.607	
65	Choosing to eat partially cooked food cannot prevent *Streptococcus suis* infection, such as choosing to eat only boiled pork skin in raw pork sausage.	4.51	0.98				0.781
64	Even though you are healthy, it does not mean that you will not be infected with *Streptococcus suis* from eating raw or undercooked pork.	4.79	0.58				0.616
62	Changing the color of pork without cooking it cannot kill *Streptococcus suis*, such as squeezing a lemon.	4.61	0.93				0.523
61	Drinking alcohol cannot kill *Streptococcus suis* in raw or undercooked food.	4.74	0.75				0.475
63	People with diseases such as kidney, liver, and heart disease must be more careful in choosing food from raw or undercooked pork than people with a healthy body.	4.42	1.05				0.461

Table 2 Cont.

No.	Factors	$\bar{X}$	S.D.	Component			
				1	2	3	4
Swine aspect							
28	Swine to be slaughtered must be inspected for disease within 24 hours before slaughter.	4.73	0.52	0.774			
07	A sick swine should be separated from the herd as soon as they are discovered	4.92	0.34	0.726			
35	Swine carcasses after slaughter must be stored at a specified temperature.	4.83	0.41	0.714			
39	Pork for sale must be arranged in an orderly manner, separating the pork from the internal organs and the swine's head.	4.75	0.51	0.713			
08	If sick swine are found, they should inform livestock or veterinarians for disease diagnosis.	4.86	0.34	0.681			
01	Breeding from different breeders should choose healthy breeders or have their health checked before being brought into the barn within 24 hours.	4.64	0.54	0.625			
20	Transporting swine to slaughterhouses must only be healthy swine.	4.74	0.50	0.545			
18	You should be careful with moving, gathering new herds, changing living pens, and changing food during the period after weaning, nursery, or fattening, as this may cause stress in the swine.	4.50	0.64		0.786		
21	During transport, do not allow the swine to survive on water and food for a long time.	4.48	0.75		0.766		
06	Swine farmers should not raise piglets of different ages together, especially after weaning.	4.49	0.69		0.606		
22	Before slaughter, swine must rest adequately for at least 2 - 4 hours after transport.	4.44	0.69		0.601		
23	Swine from different pens should be separated for transport.	4.56	0.64		0.585		
60	Wild boar meat is not safe from *Streptococcus suis*.	4.42	0.93		0.582		
19	Use of antibiotics that are sensitive to *Streptococcus suis* in large quantities and for a long time in piglets will completely kill the germs received from the sows. Therefore, the body does not create immunity against the disease itself.	4.25	0.86		0.577		
09	Sick swine due to infection with other diseases such as PRRS may increase the chance of being infected with *Streptococcus suis* and increase the severity of the disease.	4.60	0.62		0.550		
Environment aspect							
36	Pork butcher shops must be made of strong materials, smooth surfaces, easy to clean, not absorbing water, not less than 60 centimeters high from the floor, and able to be disinfected.	4.82	0.44	0.823			
27	Slaughterhouses must have fences, netting, and screens to prevent disease-carrying animals and insects.	4.80	0.52	0.816			
24	Vehicles transporting swine must be cleaned and disinfected before and after transport.	4.78	0.51	0.776			
26	There is a separation of entrance and exit for living animals. and animal carcasses or meat and have a good drainage system	4.75	0.50	0.758			
25	The slaughterhouse location must be free from flooding and the soil type should be stable.	4.78	0.50	0.752			
40	Cutting boards, knives, and equipment that come in contact with pork must be made of durable materials that can be cleaned and disinfected.	4.84	0.41	0.684			
13	Do not raise swine too crowded.	4.82	0.42	0.674			
15	Swine barns must have good ventilation.	4.84	0.42	0.666			

Table 2 Cont.

No.	Factors	$\bar{X}$	S.D.	Component			
				1	2	3	4
38	Clean the pork selling place and surrounding area every day.	4.82	0.44	0.599			
04	After the process of giving birth to piglets, the delivery area must be washed with disinfectant every time.	4.89	0.31	0.587			
29	Swine slaughtered and dissected from slaughterhouses that are registered with slaughterhouse standards are safer than those from unregistered slaughterhouses.	4.77	0.50	0.583			
10	Swine that die due to illness or unknown causes must be disposed of by burying them and must be away from the barn.	4.78	0.56	0.418			
68	There should be rules, regulations, and laws covering the raising, slaughtering, butchering, and selling of swine to be safe from *Streptococcus suis*.	4.59	0.66		0.852		
67	Local government organizations should have local regulations on the sale of food made from raw or undercooked pork, and in the community, there should be measures to prohibit the provision of food made from raw or undercooked pork in the community.	4.54	0.71		0.837		
69	Strict laws should be enforced against smugglers of pork of unknown origin.	4.78	0.51		0.578		
17	A house that is too close to a main road will make it easy for germs to spread into the house.	4.24	0.90			0.688	
14	Swine should not be raised in areas with high humidity.	4.54	0.64			0.680	
12	The appropriate temperature for raising swine must be appropriate according to the age of the swine.	4.54	0.67			0.650	
66	The local culture of eating raw or undercooked food, although it has been a practice for a long time, can be changed or canceled.	4.55	0.76				0.726
37	Pork meat stored in cabinets or tanks awaiting sale must be controlled at a temperature not exceeding 10 degrees Celsius.	4.66	0.67				0.603
16	Houses should be built on high ground or upland; the soil should be soil that is easily absorbed by water and drains well.	4.59	0.68				0.573

Table 3 Components and factors of prevention against *Streptococcus suis* using One Health System

One Health System	Component	Factors
Human	Hygiene of swine workers	Factor11(0.583), Factor30(0.715), Factor31(0.672), Factor32(0.527), Factor33(0.794), Factor34(0.768), Factor41(0.775), Factor42(0.822), Factor43(0.651), Factor44(0.744), Factor45(0.672), Factor46(0.721), Factor47(0.708), Factor48(0.704), Factor49(0.721), Factor50(0.821), Factor51(0.827), Factor52(0.837), Factor53(0.746), Factor54(0.631), Factor70(0.574)
	Behaviors, and beliefs that may cause disease	Factor55(0.518), Factor57(0.755), Factor59(0.766), Factor58(0.846)
	Increasing/reducing a person's risk of infection	Factor02(0.784), Factor03(0.728), Factor05(0.607)
	Personal factors that contribute to disease	Factor61(0.475), Factor62(0.523), Factor63(0.461), Factor64(0.616), Factor65(0.781)

Table 3 Cont.

One Health System	Component	Factors
Swine	Management before slaughter and pork	Factor01(0.625), Factor07(0.726), Factor08(0.681), Factor20(0.545), Factor28(0.774), Factor35(0.714), Factor39(0.713)
	Raising swine to be safe from *Streptococcus suis*	Factor06(0.606), Factor09(0.55), Factor18(0.786), Factor19(0.577), Factor21(0.766), Factor22(0.601), Factor23(0.585), Factor60(0.582)
Environment	Sanitation	Factor04(0.587), Factor10(0.418), Factor13(0.674), Factor15(0.666), Factor24(0.776), Factor25(0.752), Factor26(0.758), Factor27(0.816), Factor29(0.583), Factor36(0.823), Factor38(0.599)
	Rules, regulations, and laws for preventing *Streptococcus suis*	Factor67(0.837), Factor68(0.852), Factor69(0.578)
	Reducing disease-causing factors	Factor12(0.65), Factor14(0.68), Factor17(0.688)
	Local culture that is a risk factor for infection	Factor16(0.573), Factor37(0.603), Factor66(0.726)

Finally, the overall component of infection prevention is *Streptococcus suis* using 3 aspects of One Health System, consisting of 10 components, and 68 factors, as shown in Table 3.

5. Discussion

The data were analyzed using the Exploratory Factor Analysis method. The results of the analysis showed that the components prevent *Streptococcus suis* infection using One Health System, encompassing 3 aspects: people, swine, and environment. Each aspect consists of four human components, two swine components, and four environmental components, totaling 70 factors before the analysis. However, after the analysis, 68 factors remained. The interconnectedness of aspects within the One Health System promotes balance between aspects, preventing disease. However, an imbalance between these three aspects can lead to disease.

First, human aspects include: 1) hygiene of the swine workers 2) behaviors and beliefs that may cause disease 3) increasing or reducing the risk of infection among individuals and 4) personal factors that contribute to the disease. This is consistent with the study of Duriyasart et al., (2015), which found that the components of disease prevention and continuous education about correct beliefs and attitudes regarding raw food consumption led to appropriate behavior in preventing *Streptococcus suis* infections. Second, swine aspects include: 1) managing swine before butchering and slaughtering pork and 2) raising swine safely from *Streptococcus suis*, which is consistent with the study by Kerdsin et al., (2022). This study discusses improvements in the pork supply chain, including enhanced meat inspection regulations, improved hygiene in processing plants, and the prevention of unhealthy swine slaughter. Finally, environmental aspects include: 1) sanitation, 2) reducing disease-causing factors, 3) preparation of rules, regulations, and laws to prevent *Streptococcus suis*, and 4) local culture as a risk factor for *Streptococcus suis* infection. Components 1) and 2) are in line with the study of Boonyong et al., (2019) which found that cross-contamination could have occurred through slaughtering, meat cutting, and meat handling processes. Our study aligns with that of Ngo et al., (2011) which found that slaughterhouse swine are a major reservoir of *Streptococcus suis* serotype 2, necessitating strict hygiene at processing facilities. The third component was consistent with a study by Kerdsin (2022) which found that components that can reduce the incidence of *Streptococcus suis* require a multidimensional approach, combining efforts from the government and public health sectors through policy and regulation. The last component is consistent with the study of Duriyasart et al., (2015) which found that culture, shared beliefs in society, and personal attitudes regarding eating raw pork are common in some areas. Therefore, changes in behavioral attitudes

appropriate to cultural and traditional practices are desirable in reducing *Streptococcus suis* disease.

This study aimed to identify comprehensive preventive factors for *Streptococcus suis*, gathering information through a literature review, related research, in-depth interviews, and exploratory component analysis, as previously mentioned. It found that the components and factors preventing *Streptococcus suis* infection align with three aspects of the One Health System, with human aspects being the primary focus, followed by environmental and swine aspects, respectively. Recommendations for effectively reducing disease incidence include disease surveillance, prevention, and control, requiring cooperation from all relevant agencies, such as the Department of Livestock Development, Department of Disease Control, health networks, community leaders, local government organizations, public health agencies, and those working with swine (Sampao et al., 2022). This approach is consistent with the study by Fakfai, & Kanokthet (2023), which proposed the One Health System model for preventing *Streptococcus suis*. This model emphasizes integrating and coordinating all sectors with knowledge management and performance evaluation, aiming to reduce disease incidence in humans and swine, and manage the environment for the wellbeing of humans, swine, and the environment. A limitation of this study is that its composition has not been confirmed by Confirmatory Factor Analysis (CFA). Therefore, it recommends simultaneous implementation of infection prevention for *Streptococcus suis* across all dimensions. Future research should focus on developing prevention models for *Streptococcus suis* infection using the One Health System concept, especially in Health Zone 2, which reports the highest disease incidence in Thailand.

6. Conclusion

The present study conducted an exploratory factor analysis to identify the components crucial for preventing *Streptococcus suis* infection within the One Health System framework, focusing specifically on disease prevention components. The findings suggest that preventing *Streptococcus suis* infection requires a multidimensional approach, as all three aspects—human, animal, and environmental health—are interrelated. The One Health System concept underscores the importance of integrating efforts across all professions, sectors, and levels to achieve optimal health outcomes. Future research should focus on developing a model for *Streptococcus suis* prevention using the One Health System and expanding the geographic scope of research to include a more diverse range of contexts.

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