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An Outbreak of Gastrointestinal Illness Associated with Khmer Noodles: A Multipronged Investigative Approach, Kandal Province, Cambodia, June 2014

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Abstract

Food safety is a high priority for the Cambodian Ministry of Health, with standard operational procedures for foodborne diseases: intersectoral outbreak investigations and response finalized in 2015. On 29 Jun 2014, Kandal Provincial Health Department reported 143 patients with acute gastrointestinal illness, and 28 out of them were hospitalized. The number of patients increased to 215 within hours of the first report. A case-control study was conducted as well as laboratory testing, and an environmental survey to investigate the outbreak and institute necessary control measures. Three villages were randomly selected due to the provincial-wide distribution of the cases. A total of 37 cases and 36 controls were identified. Cases predominantly reported vomiting (97.3%) and diarrhea (75.7%). Consumption of Khmer noodles on 29 Jun 2014 was strongly associated with the illness (OR = 71.0, 95% CI = 8.6-582.2). Laboratory testing of food samples revealed *Staphylococcus aureus* and *Bacillus cereus*, which was consistent with the epidemiological and clinical findings. The investigation revealed the source as a sole local noodle producer and distributer. Environmental investigation of the noodle factory demonstrated multiple sources of contamination. The factory was temporarily shut down, and the team recommended destroying the remaining noodles. Local authorities were recommended to conduct regular inspection of the noodle factory.

Keywords: foodborne disease, disease outbreaks, gastroenteritis, Cambodia

Introduction

Contaminated food contributes to an estimated 1.9 billion cases of diarrhea cases.[1] The World Health Organization estimated that in 2010, foodborne disease contributed to approximately 600 million illnesses and 420,000 deaths.[2] In Southeast Asia, approximately one million children under five die from diarrheal diseases every year.[3,4]

Nowadays, acute foodborne infections and intoxication pose higher concern to governments and food industries when compared to a few decades ago. Some of the emerging issues include impact of foodborne diseases on vulnerable population such as children, elderly and immunocompromised persons, importing traditional foods of immigrants into the countries of settlement, ease in worldwide shipment of fresh and frozen foods, and development of food industries such as aquaculture.[5] Other issues of consideration for food safety are climate change, new technologies and antimicrobial resistance.

Monitoring of trends and burden of foodborne diseases requires an effective surveillance system at local, national and international levels, and resources to investigate outbreaks. Due to limited resources, many countries rely on passive reporting mechanisms to report foodborne diseases such as event-based surveillance of media or by health care workers.

Although global networks may assist countries with identifying and tracking clusters of foodborne illnesses from imported foods, the primary burden still falls on the countries where the cases occur. Unfortunately, when outbreaks occur, these countries may not have sufficient human or financial resources to identify the source of the outbreak, and effectively implement control and prevention activities.

The rapid response team (RRT) in Kandal Province notified the Communicable Disease Control Department under the Cambodian Ministry of Health of 143 people with vomiting and acute diarrhea, and rapidly escalated to 215 people within a few hours on 29 Jun 2014. The ill individuals lived in six communes of Kandal Stueng District in Kandal Province, and received treatment at local health centers and hospital. An investigation team was assembled to investigate the outbreak by describing epidemiology of the cases, and identifying mode of transmission and etiology of the illness.

Methods

The team, made up of applied epidemiology training officers and the local and central RRT, conducted an investigation and collected food samples for laboratory testing. The team also performed an environmental investigation with a traceback process to find the source of the outbreak.

Epidemiological Investigation

The RRT in Kandal Province obtained a list of people who had attended local health centers with acute gastrointestinal illness. As the patients came from six different communes, a case-control study was conducted in one of the affected communes which was randomly selected. Three out of total 10 villages in the selected commune were further randomly selected. Definition of a case was a resident living in the selected villages who had onset of vomiting and/or diarrhea during 29 Jun to 1 Jul 2014. A control was a person who lived in a neighboring household to a case, and did not report vomiting or diarrhea between 29 Jun and 1 Jul 2014.

A standardized paper-based questionnaire was administered by face-to-face interview. Collected information included demographics, signs and symptoms, onset dates of illness, and types of food and water consumed in previous two days. Data were double-entered to ensure data quality and cleaned. The data were analyzed in Epi Info 7[6], and odds ratios (OR) and 95% confidence interval (CI) were calculated.

Environmental Investigation

An environmental survey was conducted to investigate food production and processing in the Khmer noodle factory that the RRT hypothesized as the source. The team performed a walk-through examination of the premises, observed noodle production processes, cleanliness of machinery as well as storage conditions of raw ingredients and final products. Based on the noodle distribution list provided by staff at the factory, a traceback investigation was performed to remove the products from stalls across the province.

Laboratory Investigation

The investigation team collected noodle samples and noodle ingredients (rice, flour and water) from the implicated factory, the only factory in the area with widespread distribution of fresh noodles to stalls. Samples were stored in a refrigerator and sent to Institute Pasteur du Cambodge for laboratory testing.

Ethical Issue

An ethical review was not required as this investigation was considered to be an emergency response to an outbreak.

Results

Epidemiology

Patients lived in six communes of Kandal Stueng District, Kandal Province, which is located 25 km east of the capital city, Phnom Penh (Figure 1).

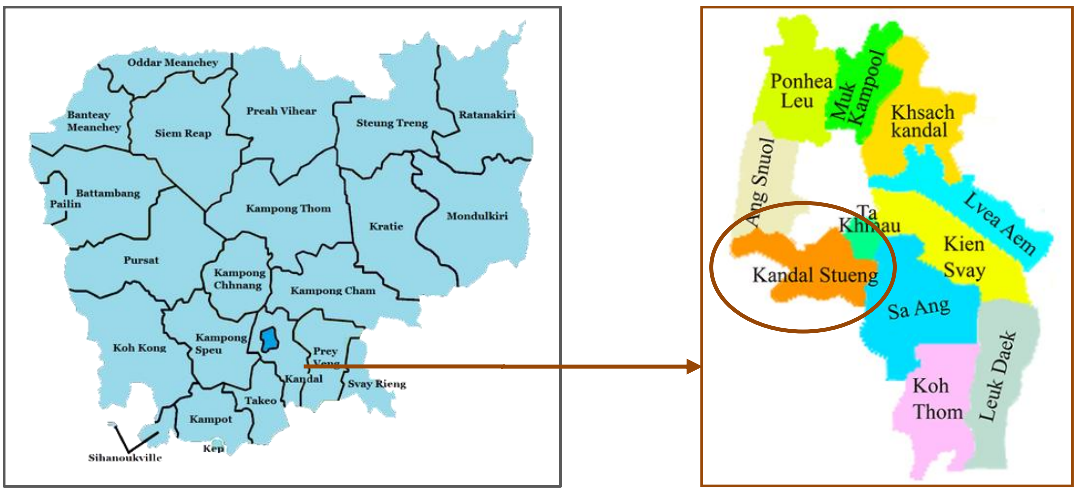

Figure 1. Map of Ampov Prey Commune, Kandal Stueng District, Kandal Province, Cambodia

Total 215 people were treated at local health centers and hospital for gastrointestinal illness. Out of 28 people who were hospitalized, 12 had severe diarrhea and were transferred to Kandal Provincial Hospital. No deaths or ongoing sequelae were reported.

The randomly selected commune was Ampov Prey Commune. Three selected villages in this commune were Ampov Prey 1, Ampov Prey 2 and Tadol 1. A total of 37 cases and 36 controls were recruited in the study. Majority of study participants were females, with 70.3% among cases and 66.7% among controls. Most were older than 16 years, with 70.3% among cases and 86.1% among controls (Table 1).

The most common symptom reported was vomiting (97.3%), followed by diarrhea (75.7%), abdominal pain (65.0%), headache (35.0%) and nausea (30.0%).

Although the cases reported consuming many types of foods, only five items with high incidence were considered for analysis, including Khmer noodles (67.1%), fish Khmer soup (42.5%), water (41.1%), rice (28.8%) and curry (15.1%). We found that those who consumed Khmer noodles had the highest OR (Table 2). The incubation period between consuming the suspected noodles and becoming sick ranged from 3-6.5 hours, with median of 4.5 hours (Figure 2).

Table 1. Sex and age composition of cases and controls from a gastrointestinal outbreak in Kandal Province, Cambodia, 29 Jun - 1 Jul 2014

Variable	Case (n=37)		Control (n=36)	
	Number	Percent	Number	Percent
Gender				
Male	11	29.7	12	33.3
Female	26	70.3	24	66.7
Age group (year)				
0-5	5	13.5	1	2.8
6-15	6	16.2	4	11.1
≥16	26	70.3	31	86.1

Environmental

A local noodle factory was implicated in the outbreak as it was the main source of raw noodles for all the food stalls involved. In the noodle factory, seven employees produced an average of 26 pots (15 kg each) of noodles per day. Khmer noodles were usually made in two batches: 5 pm (first day) and 4 am (second day).

Table 2. Analytic findings on selected food products consumed from a gastrointestinal outbreak in Kandal Province, Cambodia, 29 Jun - 1 Jul 2014

Food item	Cases (n=37)		Controls (n=36)		Odds ratio (OR)	95% CI
	Ate	Did not eat	Ate	Did not eat		
Khmer noodles	36	1	10	26	71.0	8.6-582.2
Fish Khmer soup	21	16	10	26	3.1	1.2-8.2
Curry	9	28	2	34	5.1	1.0-25.6
Rice	1	36	12	24	0.04	0.01-0.2
Water	3	34	12	24	1.9	0.4-8.8

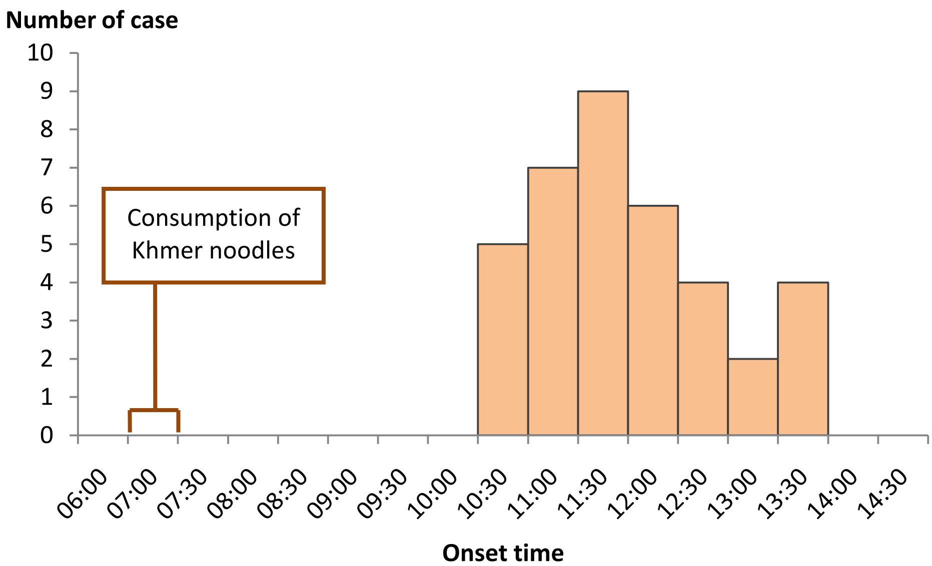

Figure 2. Distribution of cases by onset time of illness from a gastrointestinal outbreak in Kandal Province, Cambodia, 29 June 2014

First, rice was ground into flour, this flour was then kept under a stone for 2-3 hours and then boiled. The whole process took 5-6 hours. The noodles were then cut and stored at room temperature. Finally, batches of noodles were distributed by motorbikes around 6 am on the next day to noodle sellers in six communes. The transportation time from factory to seller took approximately 30 minutes. Noodle stalls cook the noodles in many different ways. The most common method for breakfast is boiling for soups.

The investigation team performed an environmental survey of the noodle factory and found several issues of concern. These findings included 11 potentially contaminated noodle pots (one pot with cut noodles and 10 pots with noodles that were not yet cut); employees with gastrointestinal symptoms in the food processing vicinity; a muddy stream running close by noodle pots on the ground; and potentially contaminated multiple points along the line of noodle production such as broken and dirty water supply system, pots on the ground by the muddy stream, and animals in the factory (Figure 3). One factory employee reported that neighbors sprayed pesticides a week before the outbreak. The neighbors also complained that the noodle factory smelled bad, especially after the rain.

Laboratory

Laboratory results revealed high level of *Staphylococcus aureus* and *Bacillus cereus* in multiple samples of old (first day) and new (second day) Khmer noodles and flour. These results implied potentially injurious contamination levels and were unfit for human consumption according to British Health Protection Agency guidelines for assessing the microbiological safety[7] (Table 3).

(a) Pots used for noodle preparation on the ground and left uncovered

(b) Inappropriate storage of rice packs to be used for noodle preparation

(c) Contaminated drainage system at the noodle factory

(d) Broken water supply at the noodle factory

(e) Inappropriate storage of uncut noodles at the factory

(f) Uncovered Khmer noodle pots accessed by animals

Figure 3. Noodle production from the implicated factory in Kandal Province, Cambodia, 29 Jun - 1 Jul 2014

Table 3. Laboratory results of food samples from a gastrointestinal outbreak in Kandal Province, Cambodia, 29 Jun - 1 Jul 2014

Type of sample	Bacteria found	Amount detected	Interpretation[7]
Rice	*Staphylococcus aureus*	<1 CFU/g	Low
	Bacillus cereus	$4.0x10^2$ CFU/g	Low
Khmer noodles (first day)	*Staphylococcus aureus*	$2.6x10^8$ CFU/g	High
	Bacillus cereus	$1.5x10^5$ CFU/g	High
Khmer noodles (second day)	*Staphylococcus aureus*	$1.7x10^9$ CFU/g	High
	Bacillus cereus	<1 CFU/g	Low
Flour	*Staphylococcus aureus*	$1.5x10^9$ CFU/g	High
	Bacillus cereus	$8.0x10^6$ CFU/g	High

Discussion

The clinical, laboratory and epidemiological findings revealed that this outbreak in Kandal Stueng District was most likely caused by consumption of contaminated Khmer noodles which were originated from the same factory though they were sold in different noodle stalls. Predominant upper gastrointestinal clinical signs and symptoms of the cases, short incubation period of 3-6.5 hours, identification of *S. aureus* and *B. cereus* in food samples, and results of the environmental investigation supported that *S. aureus* and *B. cereus* were probably the cause of the outbreak.

The findings from the case-control study implicated the Khmer noodles as the potential source. However, other food items also resulted a significant risk. The environmental findings, high bacterial load found in the Khmer noodles and flour as well as high OR for this food item suggested that the source of the outbreak was most likely to be Khmer noodles. Other food items with high OR might be due to co-contamination or eating together with the noodles.

B. cereus spores have been found in many types of foods such as milk, corn starch, rice, dried legumes and spices. Vegetative cells of some strains can start to multiply at 4°C. As the emetic toxin produced by *B. cereus* is heat stable, reheating of left-over foods may not destroy the bacteria and toxins produced. Storing food at 5°C for less than seven days may prevent *B. cereus* growth.[8]

S. aureus is commonly found in raw foods, which can be destroyed by an effective pasteurization process. The presence of this pathogen indicates post-process contamination due to poor personal hygiene and hand washing, and cross-contamination from other raw animal products. As it does not produce toxin at temperature below 10°C, refrigeration of foods should be done at less than 5°C.[8]

Both *B. cereus* and *S. aureus* are characterized by short incubation periods and short duration of illness, which fit the clinical picture of illness seen in this outbreak. Other studies also detected enterotoxigenic *B. cereus* in rice noodles, wet wheat noodles, dry wheat noodles and other foods.[9] In addition, another study showed that common ready-to-serve starchy foods such as noodles could serve as a food poisoning vehicle if temperature control was not correct.[10]

Limitations

The investigation team was unable to retrieve or test any clinical samples from the sick factory workers or cases; therefore, unable to directly link organisms in humans and foods to establish causality. The study was also constrained by small sample size of randomly selecting three villages in one commune. Due to limited investigation time, cases and controls were not matched and only a two-day food history was taken. Potential for recall bias existed as media and local authorities had already pointed to the noodles as the source of illness prior to the investigation. Moreover, selection bias could have played a role as the investigation team could not interview more controls. The investigation team also relied upon the local village chief to identify possible cases; this might have led only to people known to have eaten the noodles and who were sick to be interviewed. The investigation team did not review the possibility of contamination during transportation.

Recommendations

Several control measures were recommended for the noodle processing factory to reduce further contamination and thereby, preventing future outbreaks from consumption of the noodles.

Immediate recommendations included discontinuing delivery of Khmer noodles produced in the processing area, destroying left-over Khmer noodles, cleaning up food processing equipment and premises, restricting sick workers from the food production area, improving water supply system in the factory, protecting the production area by using netting or plastic, keeping all materials used for food processing above the ground, and utilizing safe and treated water in all noodle preparation processes. In addition, local government authorities were recommended to conduct regular inspection of noodle-making facilities and provide health education in villages about hygienic food preparation practices.

Conclusion

In summary, the findings of this study identified consumption of Khmer noodles as the likely source of the outbreak in Kandal Stueng District in Kandal Province. Noodles were contaminated by *B. cereus* and *S. aureus*, which were detected in the food items reported to be consumed by the cases and came from the Khmer noodle factory. Clinical signs and symptoms of the cases also fit with this finding. The RRT detected and responded to this event in a timely manner and ensured noodles were removed from further distribution. Our multipronged approach highlighted the advantages of integrating epidemiologic, laboratory and environmental tools for addressing disease outbreaks. The concordant findings helped to strengthen evidence needed to implement timely control measures. The introduction of food safety regulations as well as policing of these regulations in Cambodia would assist in detecting and preventing future outbreaks.

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Suggested Citation

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Seroprevalence of Brucellosis in Small Ruminants in Thailand, 2013

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Abstract

Brucellosis is a zoonotic disease caused by Gram-negative coccobacilli bacteria, *Brucella melitensis*, commonly found in small ruminants. It caused outbreaks among humans in several provinces of Thailand. The Department of Livestock Development has implemented a surveillance system for brucellosis in small ruminants since 1997. This study aimed to describe the seroprevalence of brucellosis in small ruminants and identify factors associated with spread of brucellosis in Thailand using the national surveillance data in 2013. The surveillance data in small ruminants during 2013 included herd management, movement history, location and laboratory results of tested animals from all eight veterinary laboratories in Thailand. Association between disease status at herd level and all those factors was analyzed by multivariate logistic regression analysis. The seroprevalence of brucellosis was 12.1% (438/3,626) at herd level for both goats and sheep. At individual animal level, seroprevalence were 1.4% (1,297/94,722) and 1.6% (139/8,658) for goats and sheep respectively. Free-ranging was the only one management practice significantly associated with brucellosis infection in small ruminants at herd level. Improving biosecurity of herd management, especially avoid sharing pasture and communal area should be concern to prevent introduction and spreading of brucellosis in Thailand.

Keywords: brucellosis, *Brucella melitensis*, seroprevalence, Thailand, small ruminants

Introduction

Brucellosis is a zoonotic disease in various animal species caused by Gram-negative coccobacilli bacteria of *Brucella* species. *Brucella melitensis* is commonly found in small ruminants, including sheep and goats. There are various routes of transmission such as contact with infected tissue, blood, urine, reproductive secretion or aborted fetus. The disease can cause significant economic and public health impact in several countries, especially in the Middle East, Asia, Africa, South and Central America, the Mediterranean and the Caribbean regions.[1]

Goat population in Thailand has been increasing since 1993[2] due to the goat farming promotion policy by the government of Thailand. However, there were some negative impacts from the promotion policy such as increased brucellosis outbreak in both animal and human population. Human outbreaks were found in several provinces of Thailand, including Kanchanaburi, Bangkok, Satun and Phetchabun. All of these human cases had history of either consumption of raw milk from infected goats or direct contact with infected goats.[3]

The Department of Livestock Development (DLD), Thailand has been implementing a surveillance system for brucellosis among small ruminants in Thailand nationwide since 1997.[4] Although the surveillance system and control measures for brucellosis reduce the disease occurrence, the disease still exists in all over the country. Analysis of the surveillance data was needed to identify the disease situation and find the associated risk factors. Hence, the objectives of this study were to determine seroprevalence of brucellosis in small ruminants and factors associated with disease spreading in Thailand during 2013 using the information from the national brucellosis surveillance system.

Methods

The National Institute of Animal Health and seven Regional Veterinary Research and Development Centers in Thailand conducted brucellosis testing in serum samples of small ruminants that were submitted from various provinces all over the country in 2013. Samples were collected from animals in both surveillance and movement control programs. Information on herd management such as location of farms, type of small ruminants, herd size, history of new animal introduction, raising pattern, breed, water source and type of feed was also collected.

Modified rose bengal test (RBT), enzyme-linked immunosorbent assay (ELISA) and complement fixation test (CFT) were used for laboratory serodiagnosis. If the animal was in the brucellosis free herd, it was confirmed to have brucellosis by CFT and either RBT or ELISA. An animal from the infected herd or movement purpose was regarded to have infection from a positive result of any RBT, ELISA or CFT.[4] A herd that had at least one positive sample was classified as the infected herd. The herds without a specific owner were excluded from this study.

Brucellosis situation in animal and herd levels were described using statistic indices. Association between disease status and type of animal, herd location, history of movement and herd management factors were analyzed using multivariate logistic regression. All variables with p-value less than 0.2 were included in the final model. The herd management factors included raising pattern, breed, water source and type of feed. Geographic location was divided into four regions following the regional livestock administrative system in Thailand: the northern region (regions 5 and 6), the southern region (regions 8 and 9), the central, eastern and western region (regions 1, 2 and 7) and the northeastern region (regions 3 and 4). Maps in this study were created by Quantum GIS.[5]

Results

Total 103,380 small ruminants from 3,626 herds were tested in the surveillance system in 2013. It accounted for 21.4% (103,380/482,317) of small ruminant heads and 8.7% (3,626/41,674) of ruminant herds nationwide. Total 438 herds were positive among 3,626 tested herds (12.1% herd seroprevalence, 95% CI = 11.1-13.2). In animal level, 1,297 (1.4%) goats and 139 (1.6%) sheep were seropositive (Table 1).

Median of seroprevalence in positive herds (within-herd prevalence) was 8.6% (1st and 3rd quartiles = 4.2% and 22.5%). Median herd size of the tested herds was 22 animals per herd (1st and 3rd quartiles = 11 and 44) while median herd size of positive herds was 30 animals per herds (1st and 3rd quartiles = 16 and 56).

Table 1. Result of brucellosis testing among small ruminants in Thailand, 2013

Species	Number tested		Number positive (percent)	
	Herd	Sample	Herd	Sample
Goat	3,319	94,722	384 (11.6)	1,297 (1.4)
Sheep	307	8,658	54 (17.6)	139 (1.6)
Total	3,626	103,380	438 (12.1)	1,436 (1.4)

Brucellosis infection was spreading among small ruminants throughout all regions in Thailand. High seroprevalence was found in Phichit (30.6%), Phetchabun (7.6%), Kanchanaburi (6.8%) and Loei (5.2%) provinces. Phichit Province, the highest prevalence area, is located in the lower northern part of Thailand (Figure 1).

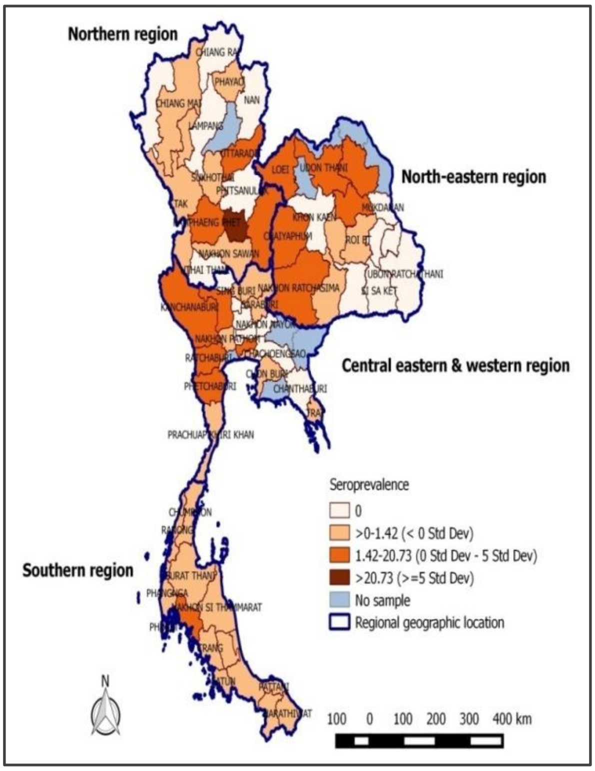

Figure 1. Seroprevalence (percentage) of brucellosis among small ruminants by province in Thailand, 2013

Environmental conditions such as weather and geographical characteristics differ with geographical location in Thailand. Thus, four geographical regions were included in the analysis for determining the associated factors. Variables with p-value were lower than 0.2 were included in final logistic regression model, including free-ranging animals in public area, herd location, middle to large herd sizes (>30 animals per herd), introduction of new animal before case detection, being goat farm, and using natural animal feeds such as grass and hay. Free-ranging was found to be the only significant factor associated with brucellosis infection in herd level in the final model.

Free-ranging herds were 2.2 times more likely to be infected than non-free-ranging herds (Table 2).

Discussion and Conclusion

As per findings from this study, lower seroprevalence of brucellosis in goats and sheep was observed in 2013 when compared with the situation in 2012 (5.1%)[6]. This finding is consistent with the decreasing prevalence during 2009 to 2013 reported by DLD[4]. This might result from prevention and control measures of brucellosis in small ruminants such as testing and slaughtering policy, and establishing of sheep and goats standard farm.

Since 2000, the standard farm policy was developed by DLD, encouraging sheep and goat farmers to request for the standard farm certification. All the standard farms must complete the brucellosis testing for all sheep and goats aged more than six months. Animals tested positive shall be slaughtered. The remaining animals in the herd shall be retested every two months until all animals in the herd show negative result for three times consecutively. At sixth month following the final testing, the herd can be declared as free from brucellosis.

Moreover, testing for brucellosis in goats and sheep prior moving from the original provinces could also contribute to decreasing brucellosis prevalence in Thailand. The provinces with high prevalence of brucellosis should be further explored as several factors might relate to high prevalence such as frequency of movement and effectiveness of control and prevention measures at local level.

The factor associated with brucellosis infection in this study was free-range system, which was similar to the finding from Reviriege's study in 2000[7]. If there were an infected animal in the free-ranging area, other animals in the same place could be infected as well. Moreover, as the bacteria could tolerate high humidity in soil and water, it would easily accumulate and infect to animals in public areas. However, a previous study identified other possible risk factors of brucellosis among small ruminants in Thailand such as goat replacement from the farm with unknown brucellosis status[8], free-ranging[6], distance to nearby farm, source of water and large herd size[9,10]. The findings might vary depending on scale and area of the studies.

The seroprevalence of brucellosis among small ruminants in this study was the best available information to determine the seroprevalence in the whole country. Nevertheless, it might not represent the situation well since the samples were collected on voluntary basis. Small-scale owners might not be requested for testing their animals.

Table 2. Association between possible risk factors and brucellosis infection at herd level among small ruminants in Thailand, 2013

Variable	Positive herd		Negative herd		Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
	Exposed	Not exposed	Exposed	Not exposed		
Free ranging	55	140	200	962	1.89 (1.33-2.67)	2.20 (1.38-3.48)
Herd size >30	145	155	725	1,330	1.72 (1.34-2.19)	1.28 (0.84-1.95)
Introduction of new animal	7	205	79	1,139	0.49 (0.21-1.03)	0.61 (0.18-2.10)
Type of small ruminant (goat)	384	54	2,935	253	0.61 (0.45-0.84)	0.84 (0.43-1.64)
Non-native breed	259	22	1,934	126	0.77 (0.49-1.25)	-
Natural feeding	113	62	575	408	1.29 (0.93-1.81)	1.08 (0.69-1.69)
Open water source	7	208	55	1,273	0.78 (0.32-1.66)	-
Region						
Northeastern	55	383	240	2,948	1.44 (1.05-1.77)	1.71 (0.33-8.91)
Northern	40	398	201	2,987	1.25 (0.87-1.81)	0.30 (0.04-2.45)
Southern	96	342	1,192	1,996	0.51 (0.40-0.65)	0.33 (0.04-2.54)
Central, eastern & western	247	191	1,555	1,633	0.51 (0.40-0.65)	Reference

Small-scale herds should also be included in the surveillance system due to potential of high negative impact to animals and farmers. Moreover, as this study used the existing information from the surveillance system, some variables were missing and information on history of animal movement might not be accurate.

In conclusion, low seroprevalence of brucellosis was found among small ruminants in Thailand during 2013. Raising goats in free-ranging area was risky for brucellosis infection. Improving biosecurity of herd management, especially having own pasture area and avoiding animal round up in communal area, should be focused to strengthen the existing control measures.

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Risk Factors of Flood-related Mortality in Phichit Province, Thailand

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Abstract

In July 2011, catastrophic flooding occurred in 65 out of 77 provinces in Thailand, affecting 9.5 million and caused 813 deaths. The highest number of death due to floodwater was found in Phichit Province. An investigation was conducted to identify risk factors for flood-related mortality. A matched case-control study was performed. A case was defined as a flood-related death and the matched control was a person residing in the same neighborhood within five years age range. Data on cases were gathered by interview with family members and witnesses while information on controls was obtained through a structured questionnaire. Total 50 flood-related deaths and 100 controls were enrolled. Majority of deaths (56%) were 31-60 years old. About 87% of deaths were males and the cause of all deaths was drowning (100%). Health problems such as central nervous system disorder, psychosis and epilepsy were observed among 34% of the deaths. A common activity at the time of death was fishing (44%). Having health problem (adjusted OR=17.3, 95% CI=1.1-275.5) and male gender (adjusted OR=14.6, 95% CI=1.4-154.2) were identified as independent risk factors of flood-related deaths. Risk communication was initiated with the related ministries and high risk activities in the floodwater were prohibited by the responsible ministries.

Keywords: disasters, drowning, floods, mortality, risk factors, Thailand

Introduction

Flooding is the most common natural disaster globally and causes devastating effects on the environment, society, economic and health.[1] Direct physical and mental impacts fall on people in the path of flooding, particularly the vulnerable groups. Physical health consequences include infections, injuries and deaths while severity depends on individual's vulnerability, characteristics of floodwater and surrounding environmental conditions. Common causes of flood-related deaths are drowning, physical injuries and diarrheal diseases.[2]

From 2001 to 2011, eight out of 10 largest natural disasters in Thailand were flooding according to the Department of Disaster Prevention and Mitigation. In the 2011-Thailand floods, 9.5 million people were affected, thousands of people were injured and 813 died from flood-related incidents.[3] The estimated economic lost was about 45.7 billion USD and ranked as the fourth costliest disaster in the world.[4]

The Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health, established a flood-related mortality surveillance system in August 2011 to monitor the magnitude of flood-related deaths and verify the cause of deaths. In September 2011, a sharply increasing trend of flood-related deaths was observed in Phichit Province and risk factors of deaths were not well understood. Therefore, an investigation was conducted to identify the risk factors, with a goal to prevent future deaths.

Methods

The national flood-related mortality surveillance system routinely collected data on flood-related cases notified from the provincial health offices (Figure 1). Drowning was defined as a process of experiencing respiratory impairment from submersion or immersion in water.[2] Physical trauma was defined as a flood-related incident of being hit by an object in the water, collapse of a building or a vehicle crash.[3]

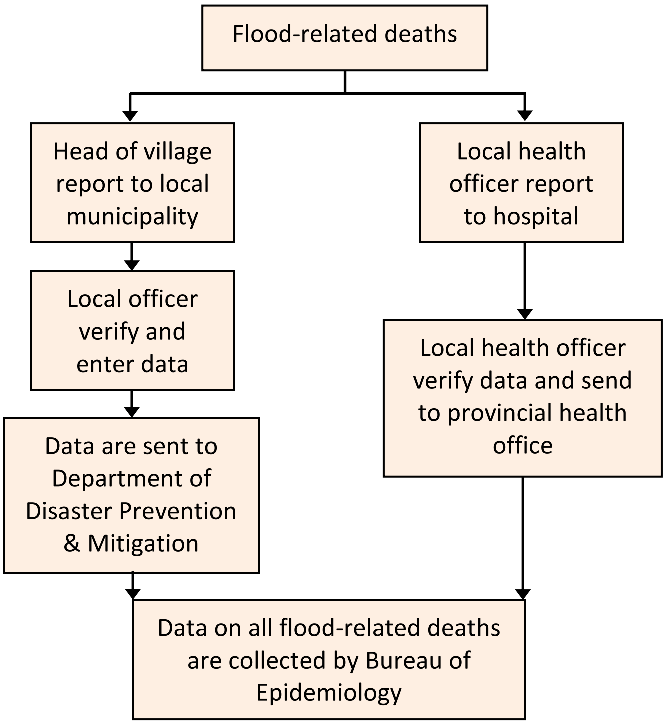

Figure 1. Flood-related mortality surveillance system of Thailand, 2011

All 77 provinces in Thailand were affected by flooding, and flood-related deaths were reported from 65 provinces, with the highest number of flood-related deaths in Phichit Province. Thus, the study was carried out in all flood-related deaths from Phichit Province. A matched case-control design was employed for different lifestyle among specific age-groups and various types of floodwater exposure in different areas. A case and two controls were matched by age and living area. Case definition of a flood-related death was obtained from the national flood-related mortality surveillance system by the Bureau of Epidemiology. A case was a resident in Phichit Province who lost the life in floodwater between July and October 2011 whereas a control was a person currently residing in the same neighborhood (left-hand side of the case's house while facing towards the house) and matched with the individual death by age (± five years range). People who mismatched or did not respond were excluded.

A structured questionnaire was developed to collect data on demographic information (age, gender, address and occupation), activities leading to death (walking, riding, driving and fishing), risk factors and surrounding circumstances (alcohol drinking, high water level and dangerous current exposure). A similar questionnaire was used to collect data from the controls as well. The standardized interview was conducted by the trained epidemiologists and public health professionals. Witnesses, family members and investigating policemen were also interviewed to obtain more information of the deaths. To compare risk factors exposed by the cases and the controls, odds ratios (OR) with 95% confidence Interval (95% CI) were calculated to examine the association between a possible risk factor and flood-related mortality. Univariated analysis by matched analysis was conducted to acquire crude OR. Variables with p-value less than 0.1 were included in multivariated analysis by conditional logistic regression. All statistical tests for this study were performed using Epi Info version 3.5.3.[5]

Results

All 12 districts in Phichit Province were affected by flooding since 31 Jul 2011. The flooding was river floods which rose slowly and stagnated for about three months and greatly impacted the living condition, economy and health. There were total 54 flood-related deaths, with crude mortality rate of 9.8 per 100,000 population during August and October 2011. The highest number of death was observed in September 2011, with 25 cases, and reduced to 16 cases in October 2011 (Figure 2).

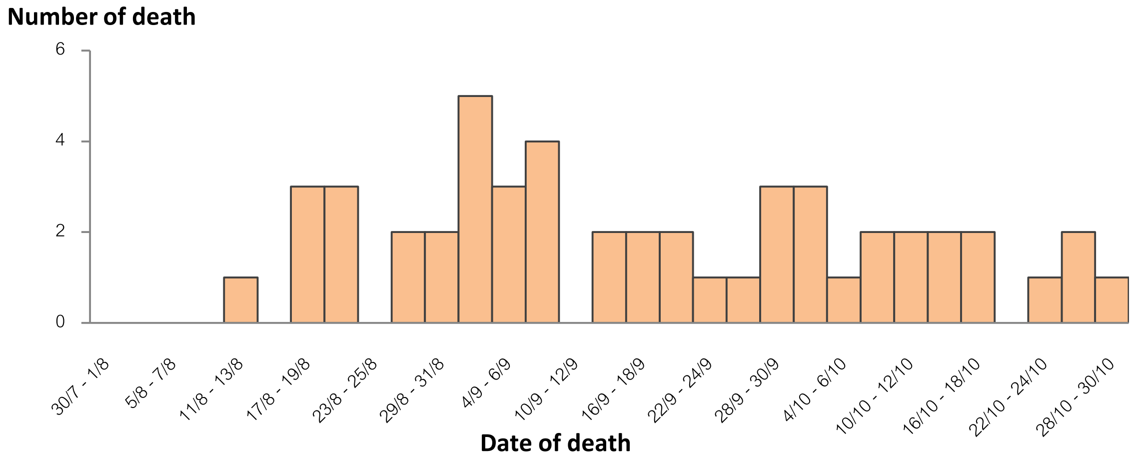

Figure 2. Distribution of flood-related deaths by date of death in Phichit Province, Thailand, July to October 2011

Deaths were reported in all districts, clustering mostly (22.2%) in Muang District which was at the center of the province.

Overall fifty decedents were included in the study, as four had incomplete data. Majority of deaths were males (88.0%). Median age was 42 years old, ranged from 3 to 88 years. Mortality proportion was the highest among working age group (31-60 years, 55.6%), followed by children <15 years (18.6%) and elderly >60 years (14.8%). Occupational status of the decedents included employee (52.0%), no occupation (18.0%) and student (14.0%). About 32% of the dead cases could not swim and 48% could swim with limited skills. The fatal cases confronted various types of currents, with mostly (47.8%) in still current. Activities related to death included mostly 44.0% fishing and 42.0% walking through floodwater. Most (81.8%) flood-related mortality events occurred in daytime (Table 1).

Having health problem at the time of death was observed in 34.0% of cases, including 9.3% with cramps or syncope and 3.7% with seizure or psychotic problems. Among the children under 15 years, 90.0% were school-aged, 60.0% had no experience of flooding and none of them could swim.

There were 33.3% of deaths in flooded man-made water reservoir, 18.5% in flooded natural water reservoir and 11.1% in the house (Table 2). All deaths occurred in floodwater and their autopsy reported as death due to asphyxia. The primary cause of all deaths was drowning.

With respect to the activities during death, more males went for fishing (87.5%) and fell into the water (71.4%) while those walked through the water were all males (100%). Overall, the remaining 50 cases and 100 controls were similar in age, living area and exposure of flooding.

The multivariate analysis revealed two potential risk factors of flood-related death, which included having health problem during flooding such as hypertension, epilepsy and mental retardation (Adjusted OR = 17.3, 95% CI = 1.1-275.5) and male gender (Adjusted OR = 14.6, 95% CI = 1.4-154.2) (Table 3).

Discussion

Phichit Province had the highest number of flood-related deaths due to geographical plains, long duration of flood and high density of population (3 times higher than the national population density)[4]. As people in the province had experienced flooding in the past, built houses to prepare for flooding such as no electricity outlet at the basement, strong structure, high ceiling on the first floor and toilet placed on the second floor. Hence, there was no electrocution or trapping in collapsed buildings and drowning was the only cause of death in the province. Nevertheless, as one of the drawbacks for the people who experienced flood frequently, the local people had low awareness on floodwater threats despite the unusual big flooding in that year, leading to risky behaviors, lack of self-protection and even death. Moreover, the flooding was caused by river flood which had low violence, yet stagnated for long duration. This could render people to expose to floodwater for months and might be relevant to high mortality as well.

The peak of flood-related death in the province was in September, which could be related to the common period for tropical storms in Thailand. In contrast to flood deaths in the United States where 75% of flash flood deaths occurred during the hours of twilight and darkness, the mortality mostly occurred during daytime in Thailand due to the water-related activities[6].

The strongest association of flood-related death as having health problems during flooding suggested that there might be a pre-existing condition causing death such as physical inability or impaired consciousness. Many people in the province were inevitably living with the floodwater and carrying out normal activities due to long duration of flooding. A study reported that population at risk of flood-related deaths included people with disabilities or illness, children, elderly and people confined in the prisons[7], which complied with the findings from this study.

Majority of flood-related deaths were in working age (31-60 years) since elderly and children stayed in the house while adults had to go out and expose to floodwater during their daily activities. The same result was observed in studies from Europe and United States[3]. However, the finding differed from the situations in Nepal[8] and Bangladesh[9] where the most affected population was children under 10 years. Children in Phichit Province died as they played or walked in floodwater and the strong current swept those vulnerabilities away.

Males were significantly at increased risk of death due to water-related activities and high risk behaviors such as fishing, traveling and walking through floodwater. Male gender was also risk factor in United States, yet with different related activities such as driving or working for emergency and supporting services[3]. A study in South Korea reported that most males died from drowning while females mostly died from structural collapse.[7] Similarly in

Nepal[8] and Bangladesh[9], as houses were destroyed by flash flood, females were more likely to be affected.

Water-related activities in Phichit Province were high risk since people did not recognize the danger of floodwater. Fishing in deep water without life-saving equipment could lead to death. Fishing and walking through floodwater were related to deaths in this study while in Australia, mostly were died from using motor vehicle during flooding (48.5%). About 26.5% of mortalities went swimming or surfing in the floodwater[10].

Table 1. Characteristics of flood-related deaths (cases) and controls in Phichit Province, Thailand, September to December 2011

Variable	Number of case (Percent) n=50	Number of control (Percent) n=100
Demographic data		
Male	44 (88.0)	33 (33)
Median age (range)	42 (3-88)	43 (4-86)
Occupation		
Employee	26 (52.0)	18 (18.0)
Student	7 (14.0)	17 (17.0)
Farmer	6 (12.0)	35 (35.0)
No	9 (18.0)	8 (8.0)
Personal information		
Able to swim	34 (68.0)	70 (70.0)
Habit of drinking alcohol	33 (66.0)	25 (25.0)
Characteristic of flooding		
Flood at home	34 (68.0)	60 (60.0)
Median flood duration (days)	28.5	21.0
Median water height in meter (range)	2.0 (0.1-5.0)	1.5 (0.1-3.0)
Flood at home last year	10 (20.0)	17 (17.0)
Water current	(n=46)	(n=70)
Still	22 (47.8)	45 (64.3)
Moderate	13 (28.3)	16 (22.9)
Rapid	11 (23.9)	9 (12.9)
Activity during flooding		
Fishing	22 (44.0)	31 (31.0)
Walking through water	21 (42.0)	71 (71.0)
Playing in water	5 (10.0)	6 (6.0)
Boating	4 (8.0)	20 (20.0)
Riding	2 (4.0)	16 (16.0)
Swimming	1 (2.0)	2 (2.0)
Fishing activity	n = 22	n = 30
Place		
Rice field	12 (54.5)	20 (66.7)
Canal	5 (22.7)	2 (6.7)
Human built resource	3 (13.6)	1 (3.3)
Side road	2 (9.1)	1 (3.3)
Method		
Walking	13 (59.1)	16 (53.3)
Boating	6 (27.3)	11 (36.7)
Riverside	2 (9.1)	3 (10.0)
Equipment		
Net	10 (45.5)	18 (60.0)
Hooking	5 (22.7)	12 (40.0)
Time		
Day	18 (81.8)	26 (86.7)
Night	4 (18.2)	2 (6.7)
Physical status		
Having health problem	17 (34.0)	2 (2.0)
Getting drunk	13 (26.0)	12 (12.0)

Table 2. Activities and circumstances of flood-related mortality in Phichit Province, Thailand, September-December 2011 (n=52)

Surrounding circumstances	Activity	Total deaths (Percent)
Flooded man-made water reservoir		18 (34.6)
	Fishing	8 (15.4)
	Playing	6 (11.5)
	Falling into	2 (3.8)
	Walking through	1 (1.9)
	Boating	1 (1.9)
Flooded natural water reservoir		10 (19.2)
	Fishing	6 (11.5)
	Walking	2 (3.8)
	Falling into	1 (1.9)
	Boating	1 (1.9)
Floodwater in the house		6 (11.5)
	Walking through	4 (7.7)
	Falling into	2 (3.8)
Floodwater near the house		5 (9.6)
	Walking through	3 (5.8)
	Falling into	1 (1.9)
	Fishing	1 (1.9)
Floodwater in rice field		3 (5.8)
	Fishing	1 (1.9)
	Walking through	1 (1.9)
	Falling into	1 (1.9)
Floodwater on the road/roadside		9 (17.3)
	Riding	4 (7.7)
	Boating	3 (5.8)
	Walking through	2 (3.8)
Driving in a vehicle		1 (1.9)

Table 3. Factors associated with flood-related mortality in Phichit Province, Thailand, September to December 2011

Factor	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Having health problem during flooding vs. healthy	88.0 (13.3-580.3)	17.3 (1.1-275.5)
Male vs. female	34.5 (9.7-122.6)	14.6 (1.4-154.2)
Walking through floodwater vs. other activities	12.7 (1.3-120.0)	14.6 (0.5-439.5)
Getting drunk during flooding vs. not getting drunk	16.3 (2.2-121.4)	1.8 (0.02-143)
Exposing floodwater level >1.5 vs. <1.5 meters	3.3 (1.3-8.3)	1.0 (0.2-4.6)
Alcohol drinking habit vs. no alcohol drinking	42.0 (8.9-197.7)	0.9 (0.1-7.7)
Exposing strong and whirl current vs. still current of floodwater	4.6 (1.59-13.1)	0.9 (0.1-6.5)

Other risk-taking behaviors like walking, boating, playing and attempting to rescue reported in this study were similar to those in Australia[10]. Most deaths related to risky activities in this study were preventable. The pattern emerged as being close to Reimer's descriptions in which mortalities occurred when residents entered their flooded homes to fetch belongings, boating and driving across flood[11]. Coates's study showed that 5.7% mortalities were due to recreational pursuits[12].

Various immediate control measures such as risk communication with the related ministries and prohibiting school-age children from playing in floodwater by the responsible ministries were launched. In addition, water-related entertainment activities were forbidden by the municipal government. High risk population was closely monitored and if needed, immediate responses were undertaken. Warning signs for people who go fishing in the dangerous or strong current places were installed in the province.

Limitation

The coverage of morbidity surveillance might not be completed and under-reported as the province staff might be exhausted with flood responses at that time. Information bias might exist in this study as data on flood-related death were derived indirectly from proxy of cases. Some quantitative data obtained may have some errors in terms of measurement of floodwater depth, velocity and alcohol level in blood. However, it was minimized by interviewing family members for personal data, and utilizing information on witness and police investigation for death scenes. The selection bias might occur in the control selection process as well, though mortality and morbidity related to physical trauma were observed.

Recommendations

To prevent flood-related mortalities, awareness on flood-related threats should be thoroughly raised among the affected population and sustained for many years, including providing health education and swimming class in schools. Early warning for detailed information of flooding such as the time of flooding and depth of floodwater must be undertaken well before the flooding began. Monitors to measure floodwater level should be installed in the flood prone areas. People with chronic diseases must be evacuated before flooding.

High risk activities in floodwater such as walking, playing and boating should be discouraged while fishing in rice-field or deep water should be forbidden. Proper risk communication and education on specific target population should be implemented as well. In the long term, sustainable education programs on flood-related threats, including locating safe places for fishing and distributing life protective equipment, should be established in the province.

In conclusion, male gender and having health problem during flooding were potential risk factors of flood-related mortality. Most of flood-related mortalities were preventable. Proper interventions in target population must be implemented before the flooding season. Some findings were specified in context of the rural of Thailand and this might be applied to the rural areas of other developing countries.

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