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Informing influenza pandemic preparedness using commercial poultry farmer knowledge, attitudes, and practices (KAP) surrounding biosecurity and self-reported avian influenza outbreaks in Nepal

Anastasia S. Lambrou[a,*], Himal Luitel[b], Rebanta K. Bhattarai[c], Hom B. Basnet[c], Christopher D. Heaney[a,d,e]

[a] *Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, United States*
[b] *Center for Biotechnology, Agriculture and Forestry University, Rampur, Chitwan, Nepal*
[c] *Department of Veterinary Microbiology and Parasitology, Agriculture and Forestry University, Rampur, Chitwan, Nepal*
[d] *Department of Environmental Health & Engineering, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, United States*
[e] *Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, United States*

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ABSTRACT

Avian influenza (AI) is a global health obstacle of critical concern as novel viruses are capable of initiating a pandemic. Recent spillover events of AI into human populations have occurred at human-poultry food system interfaces. As Nepal's poultry sector transitions to more intensified commercial production systems, it is important to examine the epidemiology of AI and the knowledge, attitudes and practices (KAP) of poultry sector workers. We conducted a cross-sectional KAP study utilizing a structured survey to interview 150 commercial poultry farmers in Chitwan District, Nepal. All commercial poultry farmers had knowledge of AI previous to the study and the majority farmers were able to identify farm-farm and poultry-human transmission mechanisms of AI. Farmers had more knowledge surrounding poultry AI symptoms as compared to human AI symptoms. Most farmers believe that AI is serious, contagious and a threat to everyone, yet only half believe it can be prevented. Individual-level personal protective equipment (PPE) uptake, such as facemask, glove and boot usage, on the enrolled farms was low and farm-level biosecurity practices varied greatly. Nine commercial poultry farms (6%) self-reported having an HPAI outbreak and 60 farms (40%) self-reported having an LPAI outbreak in the past 5 years. Layer farms had higher odds (OR: 5.4, 95% CI: 2.3–12.8) of self-reported LPAI as compared broiler farms. Poultry sector farmers face multiple obstacles when attempting to report AI to government authorities such as the fear of flock culling and the perceived lack of monetary compensation for culling. Our study provides updated KAP surrounding AI of farmers and self-reported AI farm-level epidemiology in Nepal's highest density commercial poultry production district. Commercial poultry farmers are fairly knowledgeable on AI, but do not take further protective practice efforts to implement their knowledge and prevent AI. Due to the potential role that human-poultry interfaces may play in AI emergence, it is critical to collaborate with the commercial poultry industry when planning and conducting AI pandemic preparedness mechanisms.

1. Introduction

Avian influenza (AI) is a threat to global health security due to the potential emergence of novel strains capable of initiating a pandemic. AI, influenza A subtypes that originate in birds, can spillover from birds into human populations through close contact with infected domestic or wild infected avian species. An important interface for this human-animal spillover is human contact with infected domestic food-animal birds such as poultry [1]. Individuals working in the poultry sector or directly with poultry may be at higher risk for AI as compared to the general population, and they may act as conduit spreading AI into the general population [2,3]. Consequently, it is crucial to inform avian influenza pandemic preparedness using a One Health approach integrating critical data from human, animal and environmental factors [4]. Poultry sectors in developing countries, like Nepal, are transitioning from small-scale backyard holdings to more formal commercial

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* Corresponding author.
E-mail address: anastasia.lambrou@jhu.edu (A.S. Lambrou).

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production systems, which may influence their risk for emerging zoonotic diseases like AI. Food animal production in Nepal has increased by approximately 24% in the last 10 years, driven by chicken meat, and the poultry production sector accounts for approximately 4% of total GDP [5,6]. It is critical to prevent, prepare and control AI at Nepal's human-poultry sector interfaces to curtail the potential morbidity, mortality and economic costs of a pandemic.

The Government of Nepal implemented the Avian Influenza Control Project (AICP) between 2007 and 2011 and established the National Avian Influenza Control and Influenza Pandemic Preparedness and Response Plan (NAIIPPRP), which included a special focus on protecting poultry workers from avian influenza [7]. Sporadic outbreaks of pandemic AI strain H5N1 have been occurring in poultry populations across Nepal since 2009 [5,8]. Nepal had its first human casualty, a 24-year-old male, from H5N1 in March 2019 with this being the first AI human infection globally since September 2017 [9].

KAP studies surrounding AI have been executed in many geographic settings, such as Cambodia [10], China [11,12], Egypt [13], Italy [14], and Nepal [15], and have been conducted in multiple types of populations ranging from the general community to different types of poultry sector workers. KAP studies can serve as tools to gain background data on the baseline public health situation to then strategically plan AI educational campaigns, pandemic preparedness mechanisms and disease control protocols. Our study uniquely focuses on the most commercial poultry farm dense district in Nepal, Chitwan District, and it provides novel insights on estimating the prevalence of AI on commercial farms through farmer self-reports. We focused on commercial poultry farms in Nepal due to the potential associations between intensifying poultry production systems and the risk for AI emergence [16]. Chitwan District has the highest concentration of commercial poultry farms in Nepal, accounting for 46% of all commercial poultry production in the country, and consequently, it is of critical importance to avian influenza epidemiology and biosecurity in Nepal. This district in the Terai Region of Nepal also produces approximately over half the egg supply for the entire country [17]. Chitwan District is furthermore critical to AI epidemiology in the region due to domestic bird proximity to one of Nepal's largest national parks, creating a domestic, wild and migratory bird interface for interactions and the spread of AI variants.

2. Methods

2.1. Participants and procedure

The study was a One Health poultry study collaboration between the Agriculture and Forestry University in Rampur, Nepal and the Johns Hopkins Bloomberg School of Public Health in Baltimore, United States. The study design was a cross-sectional knowledge, attitudes and practices (KAP) survey administered by local veterinary students to commercial poultry farmers. Data collection took place between July-August 2018 in Chitwan District, Nepal.

Our planned sample size was 100 commercial poultry farmers each from unique poultry farms to also assess farm-level characteristics in relationship to study outcomes. The study's sample size estimation assumed 50% of the farms in the study have had an LPAI outbreak in the past 5 years, the most conservative estimate of the two major study outcomes. The other assumptions were, 95% confidence and 10% absolute precision of the estimates, yielding a needed sample size of 97 farmers and their farms [18]. We exceeded our sample size goal and enrolled 150 farmers and their farms.

Commercial poultry farms were defined using characteristics from Nepal's Department of Livestock Services Office (DLSO), Ministry of Agriculture and Livestock Development: enclosed broiler or layer farms with biosecurity mechanisms that produced at least 100 chickens, ducks, or turkeys for the commercial market. The Chitwan District DLSO records of commercial poultry farms registered in the 2018 served as the sampling frame for the study. All enrolled farmers participated in informed consent and it was clearly stated that their status as a registered commercial farm would not be impacted if they did not volunteer to enter the study. Farmer study participation eligibility criteria included being over 18 years of age and working on a commercial poultry farm in the study area at least one day a week during the study period. We had 8 farms refuse to participate in our study; it was not apparent that these farms are different in demographics from the enrolled farms.

2.2. Structured survey interview

Data was collected through structured in-person interviews using a KAP survey, that we piloted at registered farms that were not included in the final enrollment sample. The piloting period was also used as an interviewer training and interview standardization mechanism to reduce interviewer and response biases. Farmers were also asked to consult their own poultry registers and husbandry diaries to reduce recall biases when responding to questions about poultry health and vaccination practices. Data on commercial farms located in Madi Municipality were retrieved over the phone, not in person, as landslides made travel dangerous in that area during the study period. We did not want to risk the safety of study staff and believe that phone data collection for these farms did not impact the validity of the data. The KAP survey focused on 6 major areas: farm and farmer demographics, AI attitudes, AI knowledge, individual-level farmer occupational practices, farm-level biosecurity practices, and AI surveillance practices. In the AI surveillance focus area, commercial poultry workers were asked to self-report previous highly pathogenic avian influenza (HPAI) and low pathogenic avian influenza (LPAI) outbreaks on their farms from the past 5 years. HPAI was defined as veterinarian confirmation of an HPAI outbreak or $>$ 80% die off of poultry within 2–3 days. LPAI was defined as a veterinarian confirmation of LPAI or low percentages of poultry death from suspected influenza.

2.3. Statistical analysis & study area mapping

A descriptive statistical analysis of the KAP question data was executed to obtain proportions, means and standard deviations. Logistic regressions were also performed comparing the two AI outcomes of the study, self-reported LPAI and HPAI, to farm biosecurity measures to assess any relationships between these factors and AI outbreaks in the past 5 years. Study participant data was not missing for the primary outcomes of LPAI and HPAI. Missing KAP data accounted for less than 1% of each variable and, consequently these variables were still included in the analyses. The Global Positioning System (GPS) point of farm gate or entrance was recorded for each enrolled farm using the mobile phone application Google Maps (Google, n.d.). The farms that were not physically visited in Madi Municipality were geocoded using Google Maps and the farm's address. The statistical analysis was conducted in STATA 14 (StataCorp, College Station, Texas) and all mapping was executed in ArcGIS ArcMap 10.7.1 (Esri, Redlands, California).

3. Results

3.1. Commercial poultry farmer and farm characteristics

One hundred and fifty commercial poultry farmers and their farms were enrolled into our study with an average age of 38 years old (SD = 10.7 years). The majority of commercial poultry farmers were male (68%), of Brahmin Caste (52%) and had completed at least secondary education (65%) (Table S1). One hundred and fifty commercial poultry farms from across Chitwan District were enrolled into the study (Table S2). The 150 participating commercial poultry farms included 149 chicken farms and one turkey farm. Farm size ranged from 300 to 40,000 heads of poultry with a mean of approximately 3000 birds. Enrolled poultry farms were 66% layer, 33% broiler, and 1% produced both eggs and meat products. Three farms raise commercial chickens and also kept ducks on the property and one commercial poultry farm raises both chickens and turkeys.

3.2. *Avian influenza (AI) knowledge & attitudes*

All surveyed commercial poultry workers had heard of AI previous to the study and reported multiple sources from which their knowledge derived (Table 1). The primary source of AI knowledge was the radio with 73% of participants indicating it as a source. The other most reported sources were television (62%), community members (45%) and the newspaper (43%). The majority (69%) of farmers were unable to identify any human symptoms of AI. As for knowledge surrounding poultry symptoms of AI, 31% of farmers were unable to identify a single symptom in their birds. Participants were also asked to describe AI poultry and farm transmission mechanisms. A large proportion (83%) of commercial poultry farmers identified transportation vehicles moving between farms as a transmission factor. Farmers also reported domestic poultry contact with wild birds (74%) and feed sellers (55%). Most participants were able to correctly identify methods of general influenza transmission to humans. The transmission methods with the lowest correct identification was if contact with pigs could transmit influenza to humans with 67% of respondents agreeing.

Farmers were also asked structured indicator questions about their attitudes surrounding AI (Table 1). The majority (95%) of commercial poultry farmers reported that AI is contagious and a serious disease. A large proportion (91%) of participants also responded that AI is threatening to everyone. However, the proportion of farmers believing that AI outbreaks can be prevented dropped to 51%.

3.3. *Poultry farm-level biosecurity and individual-level occupational practices*

Commercial poultry farmers were asked if they performed particular occupational practices and the frequency of those practices (Table 2). Most farmers (71%) never change their clothes before and after entering the farm and working with poultry. However, the majority of farmers (79%) wash their hands before and after entering their commercial poultry farm. Participants were also asked to self-report the frequency of their personal protective (PPE) equipment wearing while working with poultry as a three-tiered frequency scale: never, sometimes, and always. Eighty-one percent (81%) of workers sometimes change their shoes before and after entering the farm. Most farmers never wear gloves (81%), boots (60%) or aprons (94%) while coming in contact with poultry on their farm. Occupational facemask use varied with 41% of farmers never, 46% sometimes, and 13% always wearing a facemask while working with poultry. Only one farmer vaccinates their poultry against AI, however, most participants (93%) would accept an AI vaccine for their poultry if freely provided.

At the farm-level, 32% of sampled commercial poultry farms have disinfecting footbaths at their entrances (Table 3). The majority (68%) of farms do not practice vehicle disinfection at their entrances. Most farms also allow other animals, not part of the farm's livestock, to be on the property. Only one farm mandated that visitors change their clothes when visiting the farm. Forty-five percent of farms do disinfect human visitors prior to entering the farm. Most farmers (54%) also do not allow visitors to enter their farm. The majority (94%) of participants do not get vaccinated for seasonal influenza.

3.4. *Self-reported avian influenza (AI) surveillance and practices*

Nine commercial poultry farms (6%) self-reported having an HPAI outbreak in the past five years. Forty percent (40%) of commercial poultry farms reported having an LPAI outbreak in the past five years. Six of the nine (67%) farms that self-reported an HPAI outbreak had also reported an LPAI outbreak in the past five years. Farms that reported

Table 1
Commercial Poultry Farmer Self-Reported Avian Influenza (AI) Knowledge and Attitude Indicators, N=150 farmers in Nepal;

Avian Influenza (AI) Indicator	Farmer No. (%)
Have you heard about avian influenza (AI) before this study?	
Yes	150 (100.0)
No	0 (0.0)
Which of the following sources have you learned about AI from?	
Newspaper	64 (42.7)
Radio	109 (72.7)
Television	93 (62.0)
Internet	16 (10.7)
Social media	20 (13.3)
Community members	67 (44.7)
Hospital/physician	10 (6.7)
Government	6 (4.0)
What are the human symptoms of AI?	
Fever	36 (24.0)
Cough	34 (22.7)
Sore throat	25 (16.7)
Congestion	3 (2.0)
Malaise	4 (2.7)
Chills	6 (4.0)
Don't know	103 (68.7)
How will you know if your poultry have AI?	
Loss of appetite	50 (33.3)
Respiratory issues	41 (27.3)
Death/post-mortem	77 (51.3)
Don't know	46 (30.7)
How is AI transmitted to poultry farms?	
Transportation on and off farms	124 (82.7)
Feed sellers	82 (54.7)
Wild bird contact	111 (74.0)
Don't know	15 (10.0)
Can you get influenza from:	
Contact with live poultry	
Yes	139 (93.3)
No	10 (6.7)
Contact with pigs	
Yes	100 (67.1)
No	49 (32.9)
Environment	
Yes	137 (92.0)
No	12 (8.0)
Contact with/eating uncooked poultry	
Yes	141 (94.6)
No	8 (5.4)
Contact with/eating raw eggs	
Yes	139 (93.3)
No	10 (6.7)
Contact with wild birds	
Yes	139 (93.3)
No	10 (6.7)
Contact with saliva, nasal secretions, feces and fomites of infected birds	
Yes	131 (87.9)
No	18 (12.1)
Can bird flu be transmitted from animal to animal?	
Yes	139 (92.7)
No	9 (6.0)
Don't know	2 (1.3)
Is AI contagious?	
Yes	143 (95.3)
No	1 (0.7)
Don't know	6 (4.0)
Is AI a serious disease?	
Yes	142 (94.7)
No	3 (2.0)
Don't know	5 (3.3)
Can AI be prevented?	
Yes	77 (51.4)
No	41 (27.3)
Don't know	32 (21.3)
Is AI threatening to everybody?	
Yes	135 (90.6)
No	6 (4.0)
Don't know	8 (5.4)

Table 2
Commercial poultry farmer individual-level occupational practices, N=150 farmers in Nepal;

Individual-level Occupational Practices	Farmer No. (%)
Changing your clothes before and after entering the farm	
Yes, before and after	5 (3.3)
Yes, only before	38 (25.4)
Yes, only after	0 (0.0)
Never	107 (71.3)
Changing your shoes before and after entering the farm	
Never	27 (18.0)
Sometimes	122 (81.3)
Always	1 (0.7)
Glove use	
Never	122 (81.3)
Sometimes	19 (12.7)
Always	9 (6.0)
Facemask use	
Never	62 (41.3)
Sometimes	69 (46.0)
Always	19 (12.7)
Boot use	
Never	90 (60.0)
Sometimes	33 (22.0)
Always	27 (18.0)
Apron use	
Never	141 (94.0)
Sometimes	4 (2.7)
Always	5 (3.3)
Handwashing practices before and after entering the farm	
Yes, before and after	118 (78.9)
Yes, only before	3 (2.0)
Yes, only after	23 (15.3)
Never	4 (2.7)
Do you get vaccinated with the seasonal influenza vaccine?	
Yes	9 (6.0)
No	141 (94.0)

Table 3
Commercial poultry farm-level biosecurity practices, N=150 farms in Nepal;

Farm-Level Biosecurity Practices	Farm No. (%)
Disinfectant footbath at farm entrance	
Yes	48 (32.0)
No	102 (68.0)
Disinfect vehicles at farm entrance	
Yes	48 (32.0)
No	102 (68.0)
Farm completely fenced	
Yes	36 (24.0)
No	114 (76.0)
Other animals are allowed on farm	
Yes	100 (66.7)
No	50 (33.3)
Farm visitors must change clothes	
Yes	1 (0.7)
No	149 (99.3)
Disinfect all farm visitors	
Yes	67 (44.7)
No	83 (55.3)
Do not allow farm visitors	
Yes	81 (54.0)
No	69 (46.0)
Vaccinate your poultry against AI	
Yes	1 (0.7)
No	149 (99.3)
Would vaccinate poultry against AI if a vaccine was freely provided	
Yes	140 (94.0)
No	9 (6.0)

HPAI, LPAI and both types of outbreaks are geographically scattered in areas of higher human population density in Chitwan District (Fig. 1). The majority of farms (61%) report mass poultry deaths to local veterinarians.

Most farmers will also first report suspected AI in their poultry to a local veterinarian (58%) and secondarily to government officials (34%). Farmers were also asked to report the major barriers for commercial poultry farmers to report AI to the proper government agencies (Table 4). The primary obstacles farmers indicated were the fear of need to cull their entire flock (63%), and the lack of monetary compensation mechanisms to reimburse farmers for culling their own flock (55%). The other factors farmers identified were the lack of knowledge surrounding AI reporting mechanisms (15%) and the loss of farm prestige (9%). We also asked participating farmers if they knew about the actions and policies that Government of Nepal initiated and supported such as the Avian Influenza Control Project (AICP) and the Joint Health and Agriculture National Avian Influenza and Influenza Pandemic Preparedness and Response Plan (NAIIPPRP). Fifty-eight percent (58%) of farmers indicated knowledge surrounding these government initiatives with 42% of poultry farmers unaware that these initiatives exist.

3.5. *Biosecurity practices and previous influenza outbreaks*

Through logistic regression, we examined the relationships between farm-level demographics and biosecurity practices and LPAI and HPAI (Table 5). Strong statistical evidence did not link any farm-level character or practice to the occurrence of HPAI outbreaks in the past 5 years. Farm size and LPAI exhibited an increasing stepwise odds relationship with increases in poultry population increasing the odds of an LPAI outbreak. The relationship does not have strong evidence and exhibits large confidence intervals due to the small sample sizes in the farm size strata. This relationship trend was not present for the avian influenza outcome of HPAI. Some evidence exists that farm type may be associated with LPAI outbreaks. Layer farms had 5.4 (95% CI: 2.3–12.8) the odds of LPAI as compared to broiler farms. Completely fenced commercial poultry farms have 3.1 (95% CI: 1.4, 6.8) the odds of LPAI as compared to farms without fences. Self-reported outbreaks of LPAI had a slightly positive association with reporting an HPAI outbreak in the past 5 years. Farms that had reported having an LPAI in the past 5 years since summer 2018 had 3.2 times the odds (95% CI: 0.8, 13.4) of having reported an HPAI outbreak in the past 5 years as compared to farms who did not report an LPAI outbreak.

4. Discussion

Unique access to access to Chitwan District's commercial poultry sector and trust building with farmers allowed us to study the KAP surrounding AI prevention, preparedness and control. We examined individual-level and farm-level characteristics and AI surveillance to inform pandemic preparedness mechanisms and communications to vulnerable populations. Knowledge surrounding the existence of AI amongst commercial poultry farmers was widespread. The majority of farmers learned about AI through different media channels with radio, television and newspaper being most prevalent. The government of Nepal uses these specific media sources to disseminate public health information and may serve as effective future pandemic preparedness risk communication targets. Farmers also utilize other members of the community for sources of information and thus it may be important to not only educate poultry sector workers but also entire communities. AI symptom knowledge responses demonstrated that the farmers had higher knowledge of AI symptoms in poultry as compared to symptoms in humans. Most farmers were able to identify farm to farm transmission mechanisms and poultry to human mechanisms. It was important to learn that the awareness surrounding the potential transmission of influenza from live poultry to humans was very high. The transmission mechanism with the lowest affirmative response rate had to do with humans contracting influenza from pigs. It is critical to inform poultry farmers of the multiple zoonotic transmission pathways and the influenza mixing vessel nature of pigs. Pig raising is also not as prevalent as poultry production in Nepal.

The vast majority of commercial poultry farmers responded that AI is

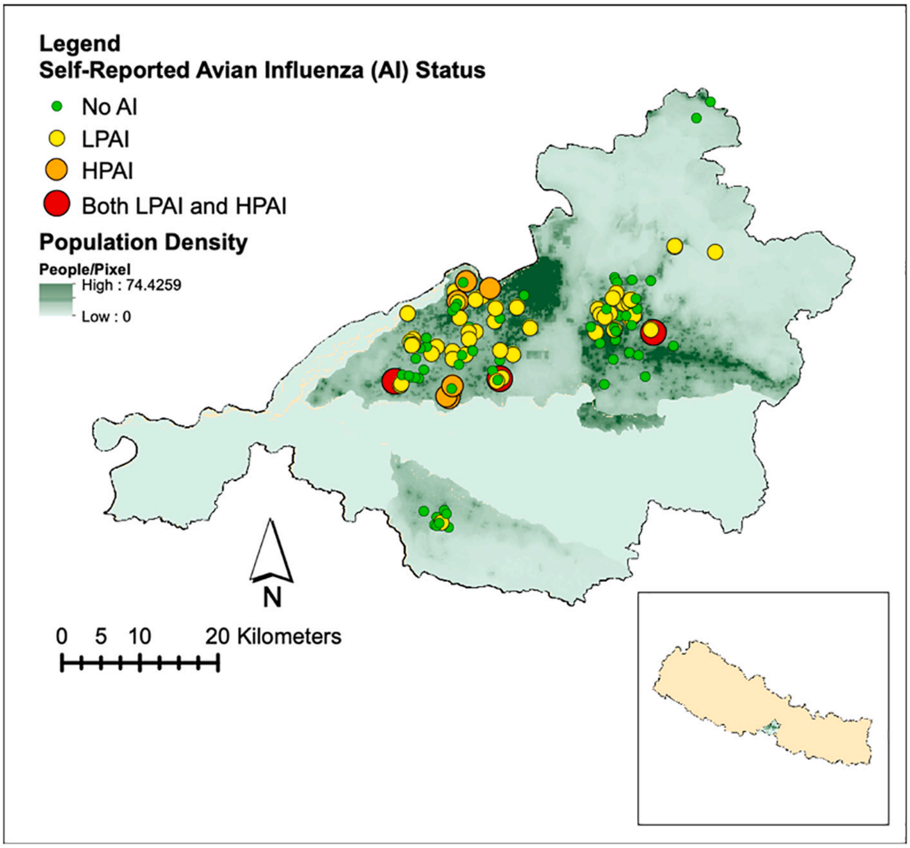

Fig. 1. Map of Chitwan District, Nepal with participating commercial poultry farms (N = 136) and their respective self-reported avian influenza (AI) status from the past 5 years, 2013-2018, and the underlying human population density. 14 farms (9%) mapped outside the study area and were not included in this map, potentially due to mobile service issues in rural border areas of the district.

contagious, serious, and threatening to everyone with proportions over 90%. However, interestingly only half of farmers thought that AI can be prevented. Preventative practices and behaviors exist for AI and consequently it will be important to target this attitude through further communications and planning. For effective uptake of practices and recognition of the threat of AI, commercial poultry farmers will need to internalize that AI can be prevented especially through cooperative practices and reporting. It appears that more AI protective efforts are taken at the farm-level as compared to the individual worker-level. The most adhered to occupational disease prevention practice was hand washing. The commercial poultry farmers had low uptakes of personal protective equipment (PPE) and did not change their clothing before and after entering the farm. The most frequently worn PPE were boots and masks. The least worn PPE were aprons and gloves. These PPE results are fairly consistent with previous KAP research conducted on other poultry sector workers in 2012 in Nepal [15]. However, Nepal's farmer PPE uptake is lower than that recorded in developed countries such as Italy [14].

Influenza vaccination practices in both animals and humans are extremely low. One farmer reported vaccinating their poultry against AI, which is currently not supported by the Government of Nepal and this activity may be misreported or due to unapproved procurement of the vaccination. However, it was critical to learn that uptake would potentially be high if the vaccine was provided to farmers for their poultry by an agency, such as Nepal's Department of Livestock Services Office (DLSO). It is also critical to integrate poultry sector workers, such as commercial farmers, into seasonal and pandemic influenza vaccination plans to potentially decrease the probability of novel virus emergence and to promote vaccination uptake and distribution systems [19]. A large majority of farmers (83%) indicated that a major farm to farm transmitter of AI are transportation vehicles, however, only 32% of farmers disinfect these transportation vehicles that may have the potential to circulate viruses. The knowledge of transmission mechanisms may exist, yet farmers are not implementing the protective measures to address those mechanisms at the farm-level. Disconnects exist between farmer knowledge and attitudes and the practices associated with AI risk.

The LPAI self-reported prevalence was larger than expected with many farmers reporting ongoing H9 outbreaks while we were conducting the data collection [6]. Larger population poultry farms may be at higher risk for both LPAI and HPAI due to more viral shedding and potentially higher density of birds contributing to AI farm transmission dynamics. Higher density of birds may lead to more effective or faster spread of AI within the farm population. Layer farms may be associated with higher rates of LPAI outbreaks as compared to broiler farms due to longer production cycles as poultry are alive and interacting for longer periods of time. This relationship is consistent with previous literature examining farm risk factor for LPAI in other settings such as the Netherlands [20] and Australia [21]. The potential positive relationship between farms with fences and LPAI was not anticipated as fences may help protect farms by keeping transmitting factors out such as other animals, humans or fomites. However, fenced farms may also be a proxy for other characteristics such as farm size. The major barriers that prevent poultry farmers from reporting AI to the government should be targeted through pandemic preparedness activities. The fear of culling and perceived lack of compensation for culling may drive farmers to not report AI potentially causing major transmission consequences. Early AI reporting is critical to disease control and pandemic prevention. It is important foster a culture of AI reporting and addressing farmers' barrier concerns can inform this process.

Table 4

Self-reported avian influenza (AI) HPAI and LPAI surveillance and AI reporting practices, N=150 farms in Nepal.

Avian Influenza (AI) Self-Reported Surveillance and Practices	Farm No. (%)
Self-reported highly pathogenic avian influenza virus (HPAI)[a] in the past 5 years	
Yes	9 (6.0)
No	141 (94.0)
Self-reported low pathogenic avian influenza virus (LPAI)[b] in the past 5 years	
Yes	60 (40.0)
No	90 (60.0)
Who do you report mass poultry death to?	
Local veterinarian	92 (61.4)
Government officials	50 (33.3)
Veterinarian and government officials	3 (2.0)
Do not report	5 (3.3)
Who will you inform first if your poultry have AI?	
Local veterinarian	87 (58.0)
Government officials	51 (34.0)
Veterinarian and government officials	2 (1.3)
Do not report	10 (6.7)
What are the major barriers preventing poultry farmers from reporting AI to the government?	
Fear of needing to cull entire flock	95 (63.3)
Lack of monetary compensation for culling flock	83 (55.3)
Loss of farm prestige	14 (9.3)
Do not know reporting mechanisms/lack of knowledge	23 (15.3)
Do you know about the actions and policies taken by government after influenza outbreak?	
Yes	87 (58.0)
No	63 (42.0)

[a] HPAI case definition: veterinarian confirmation of an HPAI outbreak or >80% die off of poultry within 2-3 days.

[b] LPAI case definition: veterinarian confirmation of LPAI or low percentages of poultry death from suspected influenza.

Table 5

Relationships between farm-level characteristics and self-reported avian influenza (AI) outbreaks, HPAI and LPAI, from the past 5 years using logistic regression analysis, N=150 farms in Nepal.

Farm-level Characteristics	LPAI OR (95% CI)	HPAI OR (95% CI)
Farm size (poultry heads)		
<500	*Ref*	*Ref*
500-1,000	2.3 (0.2, 22.0)	1/no events
1,001-2,000	4.4 (0.5, 38.3)	0.4 (0.03, 4.7)
2,001-5,000	7.5 (0.8, 68.1)	1.3 (0.2, 7.4)
>5,000	8.75 (0.9, 81.3)	0.4 (0.04, 4.9)
Farm type		
Broiler	*Ref*	*Ref*
Layer	5.4 (2.3-12.8)	4.2 (0.5, 34.7)
Both	1/no events	1/no events
Disinfectant footbath at farm entrance		
No	*Ref*	*Ref*
Yes	0.9 (0.4, 1.7)	1.1 (0.3, 4.5)
Disinfect vehicles at farm entrance		
No	*Ref*	*Ref*
Yes	1.0 (0.5, 2.0)	2.8 (0.7, 11.1)
Farm completely fenced		
No	*Ref*	*Ref*
Yes	3.1 (1.4, 6.8)	1.6 (0.4, 6.9)
Other animals are allowed on farm		
No	*Ref*	*Ref*
Yes	1.0 (0.5, 2.0)	1.8 (0.4, 9.0)
Farm visitors must change clothes		
No	*Ref*	*Ref*
Yes	1/no events	1/no events
Disinfect all farm visitors		
No	*Ref*	*Ref*
Yes	1.4 (0.7, 2.8)	1.6 (0.4, 6.2)
Do not allow farm visitors		
No	*Ref*	*Ref*
Yes	0.8 (0.4, 1.5)	0.7 (0.2, 2.6)
LPAI outbreak in the past 5 years		
No	*Ref*	*Ref*
Yes	-	3.22 (0.8, 13.4)

The limitations of the study are rooted in its small sample size and reliance on self-reported measures for both the AI outcomes of LPAI and HPAI and the KAP indicators.

It is much easier to self-report HPAI as compared to LPAI due to the high death indications. Our self-reported AI outbreak case definitions are not very specific and were developed to be sensitive to capturing the outcomes. We were unable to validate these measures using laboratory methods, and we may be overestimating AI prevalence measures as farmers may have mistaken poultry deaths for influenza instead of other potential poultry pathogens such as Newcastle Disease. This is a cross-sectional study and we are unable to draw correlations farm biosecurity practices and AI outbreak outcomes due to temporality. However, we aimed to start examining critical research questions surrounding farm-level biosecurity indicators and AI risk. The results of this KAP study may also not be generalizable to the entire country of Nepal or South Asia region. Poultry production practices may vary greatly between settings, however, out study provides insights on the most active commercial poultry production region in Nepal. The observed practices may become adopted into other areas as poultry production intensifies further and spreads geographically. Further research using different study designs, populations and validated pathogen detection techniques are needed to better understand the risk of AI at these human-poultry interfaces. Future research is also needed to better understand why the uptake of specific individual-level and farm-level protective practices are low and how to increase compliance.

5. Conclusions

Our KAP study serves as a tool to analyze avian influenza-related risk and activities at the individual farmer and farm-levels to best inform the strategic allocation of resources and messaging. Developing countries, like Nepal, must utilize limited resources systematically to ensure effective and sustainable disease control and preparedness mechanisms. Commercial poultry farmers work at intensifying human-poultry interfaces that may be critical to AI transmission dynamics. Due to the potential role that human-poultry interfaces may play in AI emergence, it is critical to also collaborate with the commercial poultry industry when planning and executing AI pandemic preparedness mechanisms. Understanding the current KAP on commercial poultry farms facilitates improving local AI surveillance systems and pandemic preparedness practices. Preparing potential human-poultry spillover hotspots in resource-poor settings may help control AI outbreaks before they emerge into pandemics.

Ethics approval and consent to participate

Ethical approval for the study was received by the Agriculture and Forestry University, in Rampur, Chitwan District, Nepal, Institutional Review Board (IRB). Informed consent was obtained by each study participant before enrollment and participation in the study. Written consent was obtained from literate participants. If a potential participant was illiterate, their thumbprint and the signature of a third-party observer was obtained.

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Authors' contributions

ASL, HL, RKB, and HBB designed the study and ASL, HL, RKB, HBB, and CDH created the study survey tool. HBB was the in-country research team lead. ASL, HL, RKB, HBB, and the One Health Research Team collected the study data. ASL and CDH analyzed the data and drafted the manuscript. All authors edited, read, and approved the final manuscript.

Availability of the data and materials

The datasets generated and analyzed during the current study are not publicly available due to requirements of the Institutional Review Board (IRB) of the Agriculture and Forestry University, in Rampur, Chitwan District, Nepal but are available from the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

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