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Determinants of Knowledge and Biosecurity Preventive Behaviors for Highly Pathogenic Avian Influenza Risk Among Chinese Poultry Farmers

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SUMMARY. Biosecurity measures are the first line of defense against highly pathogenic avian influenza (HPAI) on farms. It is generally recognized that an individual's behavior can be influenced by the knowledge they possess. However, empirical study has not reported an association between poultry producers' awareness of HPAI symptoms and their actual biosecurity actions. The aim of this study is to classify knowledge items of HPAI by exploratory factor analysis (EFA) and to examine the determinants of different types of knowledge and the effect of different types of knowledge on biosecurity preventive behaviors (BPBs). The survey ($n = 297$) was conducted using a questionnaire to measure the level of awareness of items related to HPAI and the actual adoption of BPBs among poultry farmers in the Chinese province of Jiangsu. The EFA revealed three main types of knowledge, which were categorized as avian influenza (AI) epidemic characteristics, primary biosecurity preventive knowledge (basic biosecurity preventive knowledge against AI), and essential biosecurity preventive knowledge (crucial biosecurity preventive knowledge against infection of AI). Multivariate regression showed that only poultry farmers' awareness of essential biosecurity preventive knowledge was positively associated with their actual BPBs. Additionally, educational attainment, number of years of experience raising poultry, farming operation size, and training were associated both with BPB and most of the knowledge factors or knowledge items. Training of existing poultry farmers is probably a feasible scheme; furthermore, the training should focus on the essential biosecurity preventive knowledge. On the other hand, policy initiatives to encourage large-scale poultry farming while discouraging small-scale backyard poultry husbandry would be an effective method of improving the management standards of rural poultry farming.

RESUMEN. Determinantes del conocimiento y las conductas preventivas de bioseguridad contra el riesgo de la influenza aviar de alta patogenicidad entre los avicultores chinos.

Las medidas de bioseguridad son la primera línea de defensa contra la influenza aviar altamente patógena (con las siglas en inglés HPAI) en las granjas. En general se reconoce que el comportamiento de un individuo puede ser influenciado por el conocimiento que posee. Sin embargo, el estudio empírico no ha reportado una asociación entre el conocimiento de los productores avícolas acerca de los signos de la influenza aviar altamente patógena y sus acciones reales de bioseguridad. El objetivo de este estudio consistió en clasificar los elementos de conocimiento de la influenza aviar altamente patógena mediante un análisis exploratorio de factores (EFA) y para examinar los determinantes de los diferentes tipos de conocimiento y el efecto de diferentes tipos de conocimiento sobre las conductas preventivas de bioseguridad (BPBs). Se llevó a cabo una encuesta ($n = 297$) mediante un cuestionario para medir el nivel de conocimiento de los elementos relacionados con la influenza aviar altamente patógena y la adopción real de conductas preventivas de bioseguridad entre los avicultores en la provincia de Jiangsu en China. El análisis exploratorio de factores reveló tres tipos principales de conocimiento, que fueron clasificados como características epidémicas de la influenza aviar (IA), conocimiento primario de bioseguridad y prevención (conocimiento de bioseguridad preventiva básica contra la influenza aviar) y conocimiento de la bioseguridad esencial preventiva (conocimiento de bioseguridad preventiva crucial contra la infección por la influenza aviar). Un análisis de regresión multivariante mostró que solamente el conocimiento esencial de bioseguridad preventiva de los avicultores se asoció positivamente con sus conductas preventivas de bioseguridad. Además, el nivel de instrucción, el número de años de experiencia en la avicultura, el tamaño de la operación avícola y la formación estuvieron asociados tanto con sus conductas preventivas de bioseguridad y con la mayoría de los factores o elementos de conocimiento. El entrenamiento de los avicultores existentes es probablemente un esquema viable; por otra parte, la formación debe centrarse en el conocimiento esencial de bioseguridad preventiva. Por otro lado, las iniciativas o políticas para fomentar la avicultura en gran escala y desalentar a la avicultura de traspatio o de pequeña escala doméstica serían métodos eficaces para mejorar las los estándares de manejo de la avicultura rural.

Key words: avian influenza, HPAI, preventive knowledge, preventive behavior, biosecurity, BPB, factor analysis, Chinese poultry farmers

Abbreviations: AI = avian influenza; BPB = biosecurity preventive behaviors; EFA = exploratory factor analysis; HPAI = highly pathogenic avian influenza

Highly pathogenic avian influenza (HPAI) is a highly infectious viral disease that causes almost 100% mortality in chickens, turkeys, and quail within 2–3 days (8). Since 2004, outbreaks of HPAI/H5N1 on the Chinese mainland have necessitated the slaughter of more than 40 million poultry (14) and brought huge economic losses to the Chinese poultry industry.

Biosecurity measures are the first line of defense against HPAI (3). They have been found to be effective not only in preventing and controlling the spread of HPAI at the farm level (6,12) but also showed positive effects in reducing economic losses (5). However,

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the implementation of these measures on farms requires behavioral change on the part of farmers (4). Reports indicate that China has at least 44 million poultry farmers (11). Thus, to build the first line of defense against HPAI effectively, it is crucial to ensure that poultry farmers implement biosecurity measures.

Educational measures have been shown to be effective at improving HPAI preventive behavior in poultry farmers (6) because individuals' knowledge may influence their biosecurity practices on the farm (15). The intrinsic mechanism is that knowledge leads to increased self-monitoring and is also associated with an individual's ability to modify their behavior (1). However, prior empirical studies have not reported an association between poultry producers' awareness of HPAI clinical signs in poultry and their actual biosecurity actions (16).

In addition to HPAI clinical signs in poultry, knowledge of HPAI also involves understanding the characteristics of outbreaks and biosecurity prevention measures. Although one study reported that educational level and age were associated with poultry workers' awareness of HPAI epidemic characteristics (17), as far as we have been able to determine, no study in the literature has reported whether poultry farmers' awareness of the characteristics of HPAI outbreaks and ways to implement biosecurity prevention is associated with their actual biosecurity preventive behaviors (BPBs). Therefore, making clear the relationship between poultry farmers' awareness of these issues and their actual BPBs, as well as the determinants of poultry farmers' awareness of different types of knowledge on HPAI and their actual BPBs, will not only be of benefit in further clarifying the relationship between knowledge of HPAI and actual BPBs but also will be helpful for policy makers to customize detailed and effective educational programs to improve the level of biosecurity on poultry farms.

The objective of the current study is to classify various knowledge items on HPAI by exploratory factor analysis (EFA) and to determine the association between knowledge about AI and biosecurity as reported by farmers and measures included in reported biosecurity plans.

MATERIALS AND METHODS

Study location and sampling. Jiangsu province is reported to have at least 1.1 million poultry farmers (11) and was one of the main provinces involved in the Chinese mainland outbreak of HPAI (13). Because of its geographic proximity and good working relations with local government, it was relatively easy for the researchers to gain access to the farmers. Therefore, Jiangsu province was selected as the location of this survey. Additionally, HPAI viruses cause severe infection in chickens (9), and chicken production is the most common form of poultry farming in China (11). Hence, in the interests of consistency and to avoid the influence of farmers' risk perception of HPAI for other poultry species, only chicken farmers were included in this study.

Subjects were recruited by a method of mixed stratified sampling and random sampling. First, the cities of Suqian, Nantong, and Zhenjiang, located respectively in the northern, central, and southern parts of Jiangsu province, were selected at the prefectural level. Second, among those selected prefectural-level cities, two county-level units were randomly selected. Third, within each county-level unit, two districts were randomly selected. Fourth, three villages were randomly selected from each selected district. Finally, 10 poultry farmers within each selected village were randomly selected from the lists of names provided by local veterinary bureaus that are mainly responsible for controlling the avian influenza outbreaks. The research investigator conducted face-to-face interviews with the selected farmers.

This survey was conducted between November 2013 and January 2014, which is the avian influenza (AI) epidemic season in China, after obtaining the appropriate ethical approval from local veterinary bureaus. To obtain their consent to participate in the study, all the selected chicken farmers were given an oral explanation of the purpose of the study at the beginning of the interview. Then, a standardized questionnaire was used to complete the face-to-face interview. A total of 297 subjects completed the interview, giving a response rate of 82.5%. The other 63 refused to participate because of lack of time or other unstated reasons.

Study instrument. The questionnaire is divided into three sections. The first part was the measurement of 15 specific knowledge items on HPAI. The results are presented in Table 1. The second part was the measurement of actual BPBs, including 10 questions that asked respondents whether they had adopted each of 10 biosecurity measures in their routine husbandry practices. The results of this can be seen in Fig. 1. The third section covers demographic information (including: gender, age, educational attainment, and number of years of experience raising chickens), farm operation size (amount of livestock on hand at the time of the survey), proportion of total household income from chicken farming, and related information (including previous incidence of infection with HPAI in their own poultry, previous attendance at preventive training targeted at preventing and controlling HPAI, and distance to the nearest poultry farm).

To understand the level of awareness for each knowledge item, we framed knowledge items as dichotomous (yes/no) questions of the general form: "Have you ever heard of . . . ?" To assess the adoption of actual BPBs, we asked participants questions in the form: "Have you adopted . . . in your routine husbandry practices?" All interviews were conducted in Chinese. The items presented in English in this paper were translated and back-translated twice to ensure equivalent meanings. We used Cronbach's alpha test to determine the level of internal consistency. The internal consistency of measurements of 15 knowledge items ($\alpha = 0.81$) and 10 actual BPB items ($\alpha = 0.63$) were acceptable. An α of 0.63 could be considered a marginal degree of consistency.

Statistical analyses. EFA was applied to arrange the 15 knowledge items into categories. Because the indicator data was nominal (1 or 0), we used the method of weighted least squares mean and variance adjustment in the EFA (2). The analysis was performed using Mplus 6.12 software. The criteria for choosing the final knowledge factors were items with a factor loading of more than 0.6 on a single factor, which can be considered a conservative approach to setting a factor loading.

Final factor loadings for each item on each factor are shown in Table 1. Based on the respective factor loadings and the meaning of each item, we categorize items K_1–K_4 as "Knowledge of avian influenza epidemic characteristics" (F_1). Items "Keeping the floor of the poultry farm dry can effectively prevent AI" (K_5) and "Good lighting and ventilation of poultry housing is helpful in reducing infection pressure" (K_6) involve basic biosecurity preventive knowledge against AI; therefore, we categorize items K_5 and K_6 as "Primary biosecurity preventive knowledge" (F_2). Items "The external and internal environment of poultry housing should be cleaned and disinfected regularly" (K_7), "Disinfection medicine should be used interchangeably" (K_8), "Conduct 'all in' and 'all out' method for each batch of chickens" (K_9), and "All personnel, vehicles, and goods that need to enter the poultry housing should be strictly controlled and disinfected" (K_{10}) involve some crucial biosecurity preventive knowledge against infection of AI; thus, we categorize items K_7–K_{10} as "Essential biosecurity preventive knowledge" (F_3). F_4 includes only one item, K_{11}, and items K_{12}–K_{15} have a factor loading of less than 0.6 on a single factor; thus, K_{11}–K_{15} are not categorized.

To examine the determinants associated with different types of knowledge factors, we first standardized the three types of knowledge

Table 1. Factor loadings of individual questionnaire items on the factors identified in the exploratory factor analysis and percentage of respondents indicating that they had knowledge of elements relevant to HPAI infection ($n = 297$).[A]

Code	Item	Factor loading				%
		F_1	F_2	F_3	F_4	
F_1: Knowledge of HPAI epidemic characteristics						
K_1	Healthy poultry is usually infected with the AI virus through the respiratory and digestive tract.	**0.793**	0.337	0.248	0.020	76.4
K_2	Wild birds are the reservoir of the AI pathogen.	**0.650**	0.171	0.407	0.028	89.6
K_3	Winter and spring are high-occurrence seasons for AI.	**0.692**	0.373	0.494	0.175	92.9
K_4	The virus antigen of AI often mutates.	**0.604**	0.218	0.263	0.183	70.4
F_2: Primary biosecurity preventive knowledge						
K_5	Keeping the floor of the poultry farm dry can effectively prevent AI.	0.326	**0.754**	0.376	−0.036	92.6
K_6	Good lighting and ventilation of poultry housing is helpful in reducing infection pressure.	0.332	**0.779**	0.337	−0.011	96.6
F_3: Essential biosecurity preventive knowledge						
K_7	The external and internal environment of poultry housing should be cleaned and disinfected regularly.	0.435	0.444	**0.867**	0.105	97.6
K_8	Different brands of disinfectant should be interchanged regularly.	0.378	0.394	**0.941**	0.061	97.3
K_9	Conduct "all in" and "all out" method for each batch of chickens.	0.412	0.362	**0.845**	0.079	96.6
K_{10}	All personnel, vehicles, and goods that need to enter the poultry housing should be strictly controlled and disinfected.	0.389	0.431	**0.990**	0.052	97.6
Other knowledge of elements relevant to HPAI infection						
K_{11}	The probability of being infected varies depending on the species of poultry.	0.073	−0.032	0.065	**0.974**	24.9
K_{12}	AI can be spread through the air, feces, feed, and drinking water.	0.414	0.209	0.218	0.004	87.5
K_{13}	The incubation period of the AI virus varies from hours to days.	0.475	0.217	0.178	0.163	64.3
K_{14}	Nutritionally balanced feed may help reduce the clinical impact.	0.366	0.458	0.258	−0.002	79.1
K_{15}	Chickens should not be raised with pigs on the same farm.	0.278	0.105	0.202	0.225	58.6

[A] Boldface in Table 1 were used to emphasize that items with a factor loading of more than 0.6 on a single factor.

factor extracted by the EFA. Then, for each of the knowledge factors, we summed the scores of the items making up the factor and standardized those scores using their mean and standard deviation. We then applied linear regression procedures to regress the standardized knowledge scores on demographic and related variables. Multivariate logistic regression was used to regress the responses to five knowledge items (K_{11}–K_{15}) on demographic and related variables. To examine the determinants associated with actual BPBs, we standardized the sum of the scores for adopted BPBs for each respondent. This was done by adding up the amount of adoption of biosecurity preventive practices and standardizing those using the mean and standard deviation. Then we applied multivariate linear regression to regress the standardized biosecurity preventive practice scores on demographic and related variables and different types of knowledge. The criterion for statistical significance was $P \leq 0.05$.

RESULTS

A total of 297 chicken farmers were recruited for this study. Their demographic characteristics are presented in Table 2. Of the respondents, 25.9% had previous experience of poultry infected with HPAI, and 66.3% had participated in relevant training targeted at preventing and controlling HPAI. According to the farmers, the nearest poultry farm is about 1 km away on average, and the average proportion of chicken income as a share of total household income was 58.22% (SD = 30.38).

With regard to knowledge of HPAI (Table 1), over 90% of respondents gave a positive answer to all the questions in the primary biosecurity preventive and essential biosecurity preventive categories. Knowledge of items on HPAI epidemic characteristics ranged from

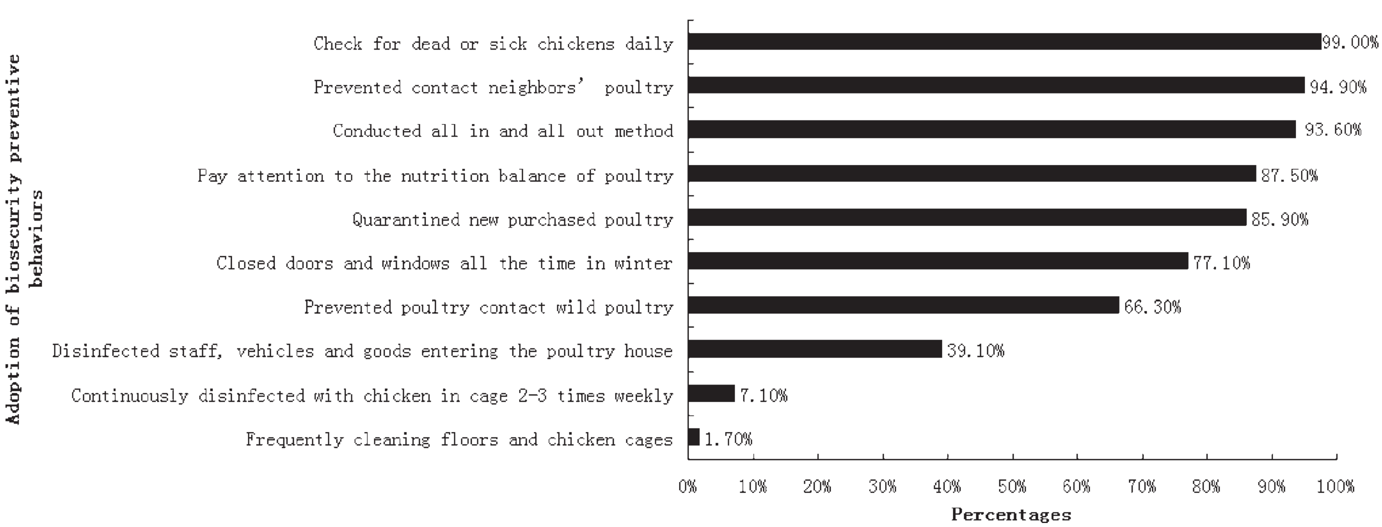

Fig. 1. Percentage of respondents reporting adoption of biosecurity preventive behaviors against HPAI ($n = 297$).

Table 2. Respondents' characteristics ($n = 297$).

Characteristic	n	%
Gender		
Female	71	23.9
Male	226	76.1
Age (yr)		
≤45	55	18.5
46–55	151	50.8
≥56	91	30.6
Education		
Primary or below	73	24.6
Junior high school	153	51.5
Senior high school or above	71	23.9
Years raising poultry		
≤10	129	43.4
11–20	123	41.4
≥21	45	15.2

70.4% to 92.9%. The specific knowledge items of "The Avian Influenza (AI) can be spread through the air, feces, feed, and drinking water" and "Nutritionally balanced feed may help reduce the clinical impact" were known to around 80% or more of respondents. Positive responses to the items "The probability of being infected varies depending on the species of poultry," "The incubation period of the AI virus ranges from hours to days," and "Chickens should not be raised with pigs in the same farms" were under 65%.

Fig. 1 summarizes the reported adoption of the 10 actual BPBs. For 3 of the 10, adoption was strong (greater than 93%), 2 of the 10 adoptions were greater than 85%, and the others were under 78%. Surprisingly, less than 10% of the respondents adopt each of the final two.

The results of the multivariate linear regression (Table 3) showed that gender ($P < 0.05$), educational attainment ($P < 0.01$), raising years ($P < 0.01$), farming operation size ($P < 0.01$), and proportion of chicken income in total household income ($P < 0.05$) were significantly associated with knowledge of HPAI epidemic characteristics. Raising years ($P < 0.01$), farming operation size ($P < 0.01$), and training ($P < 0.01$) were significantly associated with primary biosecurity preventive knowledge. Farming operation size ($P < 0.01$) and distance to the nearest poultry farm ($P < 0.05$) were significantly associated with essential biosecurity preventive knowledge.

The results from the multivariate logistic regression (Table 4) showed that respondents who were female, had an education to senior high school level or above, and underwent training were more likely to have biosecurity preventive knowledge, whereas those less than 55 yr and raising poultry for more than 21 yr were less likely to know that "The probability of being infected varies depending on the species of poultry." Respondents who were male, attained an educational of less than junior high school, operated a farm of less than 10,000 chickens, and had more years raising poultry were more likely to know that "The AI can be spread through the air, feces, feed, and drinking water."

Respondents with an educational attainment of less than junior high school, who raised poultry for less than 10 yr and more than 21 yr, were trained, and were a longer distance to the nearest poultry farm knew more, but those between 46 and 55 yr were less frequently aware that "The incubation period of the AI virus varies from hours to days." Respondents who were male, had more years of raising poultry, and were trained were more likely to know that "Nutritionally balanced feed may help reduce the clinical impact." Respondents who operated in larger farms were more likely, but those with a shorter distance to the nearest poultry farm were less likely, to know that "Chickens should not be raised with pigs in the same farms."

The outcomes of the multivariate regression (Table 5) showed that respondents' actual BPBs were significantly and positively associated with educational attainment ($P < 0.05$), years of raising ($P < 0.01$), farming operation size ($P < 0.01$), training ($P < 0.01$),

Table 3. Multiple regression coefficients β, and standard errors for demographic and related variables associated with knowledge factor scores (standardized, mean/SD).[A]

	Knowledge of HPAI epidemic characteristics		Primary biosecurity preventive knowledge		Essential biosecurity preventive knowledge	
	β	SE	β	SE	β	SE
Demographic variable						
Gender[B]	0.13*	0.13	0.11	0.14	0.03	0.12
Age[C]	−0.04	0.08	0.04	0.10	0.06	0.08
Educational attainment[D]	0.27**	0.08	−0.02	0.09	0.02	0.08
Raising years[E]	0.28**	0.07	0.20**	0.08	0.06	0.07
Farming operation size[F]	0.29**	0.11	0.20**	0.12	0.60**	0.10
Proportion of chicken income as a share of total household income	−0.12*	0.01	−0.08	0.01	0.01	0.01
Related variable						
Infected experience[G]	−0.06	0.12	0.02	0.13	−0.03	0.11
Training[H]	−0.01	0.11	0.17**	0.13	0.04	0.11
Distance to the nearest poultry farm	−0.02	0.03	−0.02	0.04	−0.10*	0.03

[A]$*P < 0.05$; $**P < 0.01$.
[B]Gender was coded 0 = female and 1 = male.
[C]Age was coded 1 = ≤45 yr, 2 = 46–55 yr, 3 = ≥56 yr.
[D]Educational attainment was coded 1 = primary or below, 2 = junior high school, 3 = senior high school or above.
[E]Years of raising was coded 1 = ≤10 yr, 2 = 11–20 yr, 3 = ≥21 yr.
[F]Farming scale was coded 1 = ≤300 chickens, 2 = 301–1000 chickens, 3 = 1001–10,000 chickens, 4 = ≥10,001 chickens.
[G]Infected experience was coded 1 = chickens have been infected with HPAI before, 0 = chickens have not been infected with HPAI before.
[H]Training was coded 1 = participated in training, 0 = have not participated in training.

Table 4. Multiple logistic regression odds ratios (OR; 95% confidence intervals, CI)[A] for demographic and related variables associated with unclassified knowledge items[B] ($n = 297$).

	K_{11}		K_{12}		K_{13}		K_{14}		K_{15}	
Predictor variable	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI
Demographics										
Gender (female *vs.* male)	0.40*	0.19–0.84	3.44*	1.07–11.06	1.76	0.87–3.56	2.39*	1.07–5.34	1.73	0.89–3.37
Age (yr)										
≤45	1.00**		1.00		1.00		1.00		1.00	
46–55	0.41*	0.19–0.86	0.27	0.04–1.96	0.41*	0.18–0.91	1.36	0.59–3.13	0.51	0.24–1.05
≥56	1.56	0.66–3.68	0.39	0.05–3.02	0.43	0.17–1.09	0.88	0.34–2.28	0.71	0.30–1.70
Educational attainment										
Primary or below	1.00		1.00*		1.00*		1.00		1.00	
Junior high school	2.40	1.06–5.37	4.08*	1.39–11.98	2.65**	1.29–5.43	1.27	0.58–2.77	1.63	0.82–3.25
Senior high school or above	3.31*	1.17–9.41	8.91	0.87–91.63	2.40	0.90–6.40	0.46	0.16–1.34	1.04	0.43–2.54
Years of raising poultry										
≤10	1.00		1.00*		1.00**		1.00**		1.00	
11–20	0.77	0.41–1.47	3.97*	1.12–14.12	1.37	0.72–2.59	2.93**	1.38–6.21	1.47	0.80–2.72
≥21	0.29*	0.10–0.84	9.44*	1.10–81.63	6.09**	2.33–15.88	2.94*	1.07–8.10	1.16	0.54–2.49
Farming operation size (No. of chickens)										
≤300	1.00		1.00**		1.00		1.00		1.00*	
301–1000	1.23	0.18–8.31	197.13**	7.67–5068.42	0.87	0.15–5.15	1.71	0.29–10.26	32.89**	3.61–299.33
1001–10,000	0.73	0.15–3.59	125.93**	10.13–1565.70	1.87	0.44–7.98	2.39	0.58–9.86	9.33*	1.72–50.57
≥10,001	0.71	0.10–4.97	0.00	0.00–0.00	1.14	0.19–6.77	3.75	0.51–27.50	14.99**	2.01–111.92
Proportion of chicken income as a share of total household income	1.01	0.99–1.02	0.99	0.97–1.01	0.99	0.98–1.00	0.99	0.99–1.01	0.99	0.98–1.00
Related										
Infected experience (infected *vs.* uninfected)	1.57	0.81–3.08	0.97	0.25–3.74	1.66	0.84–3.31	1.04	0.48–2.24	0.57	0.30–1.07
Training (trained *vs.* untrained)	1.96*	0.97–3.95	1.18	0.42–3.30	2.92**	1.56–5.47	2.14*	1.08–4.23	1.35	0.76–2.41
Distance to the nearest poultry farm	0.87	0.70–1.07	3.58	0.87–14.71	1.41*	1.08–1.84	0.97	0.79–1.20	0.73**	0.60–0.89

[A]$*P < 0.05$, $**P < 0.01$

[B]K_{11} = The probability of being infected varies depending on the species of poultry; K_{12} = AI can be spread through the air, feces, feed, and drinking water; K_{13} = the incubation period of the AI virus varies from hours to days; K_{14} = nutritionally balanced feed may help reduce the clinical impact; K_{15} = chickens should not be raised with pigs on the same farms.

and essential biosecurity preventive knowledge ($P < 0.01$), whereas respondents who knew more about primary biosecurity preventive knowledge were apparently less likely to adopt BPBs adequately ($P < 0.05$).

DISCUSSION

Three main types of knowledge were extracted from 15 related HPAI knowledge items using EFA, and factors influencing different types of knowledge and actual BPBs were examined. Although respondents in the current study all came from China, we expect that our findings can provide a reference to other countries, especially countries with similar national conditions as China.

The current study confirmed the relationship between knowledge and behavior in HPAI prevention. It also determined that essential biosecurity preventive knowledge was a significant driver for improving the practice of BPBs in poultry farmers, compared with different types of knowledge on HPAI. Essential biosecurity preventive knowledge items in the current study were directly related to poultry farmers' practice of BPBs and were more concrete guides to the implementation of preventive practices against HPAI. These items were more conducive to improving the self-efficacy of poultry farmers in controlling the spread of the HPAI virus and changed expectations about the adoption of BPBs because poultry farmers believe that they can achieve the desired effects by adopting the preventive measures.

Our survey found that the proportion of farmers who "disinfected staff, vehicles, and goods entering the poultry house" was lower than that observed in a previous study, which also indicated that receiving visitors and goods from outside was one of the main risk factors associated with HPAI virus infection in poultry farms (6). Therefore, there seems to be a greater risk of poultry being infected in Chinese poultry farms than elsewhere. Surprisingly, our study reported low frequencies of adoption of "continuously disinfected with chickens in cage 2–3 times weekly" and "frequently cleaning floors and chicken cages." This also implies a greater potential risk of poultry becoming infected.

Poultry farmers with a high level of education were likely to possess more knowledge of HPAI epidemic characteristics, routes of transmission, and the incubation period of HPAI. Moreover, the observation that more highly educated poultry farmers were more likely to adopt BPBs in practice indicated that the level of education was an important predictor of BPBs among Chinese poultry farmers.

Farmers who managed larger farms were likely to have a more comprehensive knowledge of HPAI and adopted more actual BPBs compared with an earlier study in Kenya (16). A larger farm size

Table 5. Multiple regression coefficients (β, standardized; standard errors)[A] for demographic, related variables, and knowledge factors associated with adoption of BPBs.

Predictor variables	β	SE
Demographic		
Gender[B]	0.02	0.12
Age[C]	−0.02	0.07
Educational attainment[D]	0.11*	0.08
Years of raising[E]	0.15**	0.07
Farming operation size[F]	0.17**	0.11
Proportion of chicken income as a share of total household income	−0.08	0.01
Related		
Infected experience[G]	−0.02	0.10
Training[H]	0.15**	0.10
Distance to the nearest poultry farm	0.04	0.03
Standardized knowledge factor score (mean/SD)		
Knowledge of HPAI epidemic characteristics	−0.07	0.07
Primary biosecurity preventive knowledge	−0.11*	0.05
Essential biosecurity preventive knowledge	0.54**	0.06
Unclassified knowledge items[I]		
K_{11}	−0.06	0.11
K_{12}	0.04	0.21
K_{13}	−0.02	0.11
K_{14}	−0.05	0.12
K_{15}	0.04	0.10

[A]$*P < 0.05$, $**P < 0.01$.
[B]Gender was coded as 0 = female and 1 = male.
[C]Age was coded as 1 = ≤45 yr, 2 = 46–55 yr, 3 = ≥56 yr.
[D]Educational attainment was coded as 1 = primary or below, 2 = Junior high school, 3 = senior high school or above.
[E]Years of raising was coded as 1 = ≤10 yr, 2 = 11–20 yr, 3 = ≥21 yr.
[F]Farming scale was coded as 1 = ≤300 chickens, 2 = 301–1000 chickens, 3 = 1001–10,000 chickens, 4 = ≥10,001 chickens.
[G]Infected experience was coded as 1 = chickens have been infected with HPAI before, 0 = chickens have not been infected with HPAI before.
[H]Training was coded as 1 = participated in training, 0 = have not participated in training.
[I]K_{11} = The probability of being infected varies depending on the species of poultry; K_{12} = AI can be spread through the air, feces, feed, and drinking water; K_{13} = the incubation period of the AI virus varies from hours to days; K_{14} = nutritionally balanced feed may help reduce the clinical impact; K_{15} = chickens should not be raised with pigs on the same farms.

usually implies greater economic losses if poultry are infected, forcing larger scale farmers to increase their poultry raising management standards, implying that larger farm size is conducive to poultry farmers' adoption of actual BPBs, whereas a smaller farm size increases the risk of infection and transmission of HPAI in China.

Unlike a study in Kenya, which indicated that a shorter distance to the nearest poultry farm tended to increase poultry producers' adoption of actual BPBs (16), our results did not report a significant association between the distance to the nearest poultry farm and the actual BPBs of chicken farmers. This is probably because of a lower risk perception of AI among Chinese poultry farmers (10).

Our findings show that more years of experience raising poultry and well-trained chicken farmers were more likely to possess better knowledge of HPAI and adopted more actual BPBs. This indicates that longer raising years and participation in relevant training on HPAI prevention were helpful in improving awareness levels of HPAI and adoption of actual BPBs.

Because poultry farmers usually make decisions about whether to raise poultry continuously or to stop operations temporarily based on their own judgment of market demands, such as changes in price, it was not possible to interview exactly the same respondents during the second round. A cross-sectional study was conducted to address this. To assess any causal relationship among the variables in the current study, future studies should prepare by collecting more information from poultry farmers to determine how many farmers raise poultry continuously or increase the sample size so that even if some farmers temporarily stop raising poultry because of price changes, there will still be enough samples to complete the survey. Another alternative would be to conduct a longitudinal study. On the other hand, the small sample size probably limits our scope for giving a clear and reasonable explanation of the relationship between demographic characteristics and knowledge items.

CONCLUSION

Among the different types of knowledge on HPAI prevention among Jiangsu poultry farmers, only essential biosecurity preventive knowledge was strongly associated with implementation of BPBs. Although improving general education was more likely to promote the level of adopting actual BPBs in the current study, understanding that educated members of the Chinese rural labor force tend to settle in the off-farm sector (7), training to existing poultry farmers is probably a more feasible scheme. Furthermore, the training should focus on essential biosecurity preventive knowledge. Additionally, our study results indicate that a policy incentive to encourage large-scale poultry farming while discouraging small-scale backyard poultry husbandry would be not only an effective method of improving the management standards of rural poultry farming but also would reduce the number of human-bird contacts because fewer people would be involved in poultry production.

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