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The influence of economic indicators, poultry density and the performance of Veterinary Services on the control of high-pathogenicity avian influenza in poultry

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Summary
High-pathogenicity avian influenza (HPAI) and low-pathogenicity notifiable avian influenza (LPNAI) in poultry are notifiable diseases that must be reported to the World Organisation for Animal Health (OIE). There are variations between countries' responses to avian influenza (AI) outbreak situations based on their economic status, diagnostic capacity and other factors. The objective of this study was to ascertain the significant association between HPAI control data and a country's poultry density, the performance of its Veterinary Services, and its economic indicators (gross domestic product, agricultural gross domestic product, gross national income, human development index and Organisation for Economic Co-operation and Development [OECD] status). Results indicate that as poultry density increases for least developed countries there is an increase in the number and duration of HPAI outbreaks and in the time it takes to eradicate the disease. There was no significant correlation between HPAI control and any of the economic indicators except membership of the OECD. Member Countries, i.e. those with high-income economies, transparency and good governance, had shorter and significantly fewer HPAI outbreaks, quicker eradication times, lower mortality rates and higher culling rates than non-OECD countries. Furthermore, countries that had effective and efficient Veterinary Services (as measured by the ratings they achieved when they were assessed using the OIE Tool for the Evaluation of Performance of Veterinary Services) had better HPAI control measures.

Keywords
Avian influenza – Control – Economic indicator – Eradication – OECD – OIE PVS tool – Veterinary Services.

Introduction

High-pathogenicity avian influenza (HPAI) and low-pathogenicity notifiable avian influenza (LPNAI) in poultry are notifiable diseases that must be reported to the World Organisation for Animal Health (OIE) (16). High-pathogenicity avian influenza is a highly infectious disease of poultry caused by H5 and H7 subtypes of type A influenza virus and it typically results in high mortality. Low-pathogenicity avian influenza is also caused by infections with influenza A viruses of H5 and H7 subtypes,

but it causes little or no mortality unless accompanied by secondary pathogens. The main risk from LPNAI viruses, and the reason for global efforts for their control, is that they have the capacity to change to HPAI viruses, and it is not possible to predict when this might happen. International reporting of HPAI and LPNAI outbreaks is necessary to prevent further spread through international trade, to increase global disease transparency, and to enhance knowledge of the worldwide avian influenza (AI) outbreak situation, thus allowing the development of effective, harmonised control strategies.

Local, national and regional level Veterinary Services play a key role in controlling AI by carrying out surveillance of animal diseases, including zoonoses, for early detection and rapid response (2). In order to effectively utilise financial and human resources to deal with AI control, it is important to understand the economic, social and governance factors that may affect the success and impact of control measures. Whilst following certain general principles, the control strategy for an individual country should be tailored to country-level factors such as the mixture of commercial, semi-commercial and village poultry production systems, and the availability of local financial and human resources (10).

There are variations in the ways in which countries respond to HPAI outbreaks and this paper examines some of the factors that explain these differences. More specifically, the authors analyse how a country's economic indicators, its poultry density, and the performance of its Veterinary Services influence its ability to prevent and control HPAI.

Materials and methods

Avian influenza control data

A total of 60 countries, territories or special administrative regions experienced outbreaks of HPAI in poultry between 2002 and 2010, and from data collected from Handistatus II (18) and the World Animal Health Information Database (WAHID) (19) the following parameters were calculated:

– outbreak duration in days: start date of the event until the last case has been diagnosed

– eradication time in days: start date of the event until three months after the last case has been stamped out and all affected establishments have been disinfected (in accordance with the OIE *Terrestrial Animal Health Code,* the absence of further outbreaks must be confirmed by surveillance during this three-month period [16])

– mortality rate:

$$\frac{\text{poultry deaths during an HPAI outbreak} \times 100{,}000}{\text{poultry population at a particular time in a year}}$$

– culling rate:

$$\frac{\text{total poultry culled during an HPAI outbreak} \times 100{,}000}{\text{poultry population at a particular time in a year.}}$$

Data on poultry population were obtained from the Statistical Database of the Food and Agriculture Organization of the United Nations (FAOSTAT) (7) and information on poultry density (head/km^2 of agriculture land) was obtained from the FAO Global Livestock Production and Health Atlas (6).

Economic indicators

Economic indicators allow analysis of the economic performance of a country. In this study the authors used the following economic indicators:

– gross domestic product (GDP) based on purchasing power parity

– agricultural gross domestic product (AGDP)

– percentage that AGDP contributes to total GDP (% AGDP)

– GDP per capita

– gross national income (GNI)

– human development index (HDI)

– membership of the Organisation for Economic Co-operation and Development (OECD) (3, 11, 13, 15).

Economic indicators were tested for correlation with AI control data sets.

A nation's GDP at purchasing power parity exchange rates is the sum value of all goods and services produced in the country valued at prices prevailing in the United States. This is the measure most economists prefer when looking at per-capita welfare and when comparing living conditions or use of resources across countries (3). Gross domestic product per capita is gross domestic product divided by mid-year population (15). Gross national income per capita at purchasing power parity rates is the sum of the value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad in current international dollars (15). The HDI is a summary measure of human development. It measures the average achievements in a country in three basic areas: health, education and living standards (13).

Countries which experienced outbreaks of HPAI between 2002 and 2010 were analysed in order to establish if there was an association between their GDP, AGDP, % AGDP, GDP per capita, GNI and HDI and their HPAI control data sets. For the purpose of more detailed statistical analysis, the countries were classified into least developed countries,

developing/transition countries, and developed countries using the classifications of the United Nations Statistics Division (14), as follows:

a) least developed countries: Afghanistan, Bangladesh, Benin, Bhutan, Burkina Faso, Cambodia, Djibouti, the Lao People's Democratic Republic (LAO PDR), Myanmar, Niger, Sudan and Togo (12 countries)

b) developing/transition countries: Albania, Azerbaijan, Cameroon, Chile, the People's Republic of China (China), Côte d'Ivoire, Egypt, Ghana, Hong Kong Special Administrative Region, India, Indonesia, Iran, Iraq, Israel, Jordan, Kazakhstan, the Democratic Republic of Korea (DPR Korea), the Republic of Korea, Kuwait, Malaysia, Nepal, Nigeria, Pakistan, Palestinian territories, Russia, Saudi Arabia, Serbia, South Africa, Thailand, Turkey, Ukraine, Vietnam and Zimbabwe (33 countries)

c) developed countries: Belgium, Canada, the Czech Republic, Denmark, France, Germany, Hungary, Japan, the Netherlands, Poland, Romania, Spain, Sweden, the United Kingdom and the United States (15 countries).

Countries affected by HPAI outbreaks were also divided into OECD countries and non-OECD countries and their outbreak data were compared. Member Countries of the OECD are committed to market economies backed by democratic institutions and focused on the well-being of all citizens. These countries foster prosperity and fight poverty through economic growth and financial stability. The OECD countries included in this study were Belgium, Canada, Chile, the Czech Republic, Denmark, France, Germany, Hungary, Israel, Japan, the Republic of Korea, the Netherlands, Poland, Spain, Sweden, Turkey, the United Kingdom and the United States (18 countries) (11). The non-OECD countries included were Afghanistan, Albania, Azerbaijan, Bangladesh, Benin, Bhutan, Burkina Faso, Cambodia, Cameroon, China, Côte d'Ivoire, Djibouti, Egypt, Ghana, Hong Kong, India, Indonesia, Iran, Iraq, Jordan, Kazakhstan, DPR Korea, Kuwait, Lao PDR, Malaysia, Myanmar, Nepal, Niger, Nigeria, Pakistan, Palestinian territories, Romania, Russia, Saudi Arabia, Serbia, South Africa, Sudan, Thailand, Togo, Ukraine, Vietnam and Zimbabwe (42 countries).

Performance of Veterinary Services

The OIE has developed an assessment tool – the Tool for the Evaluation of Performance of Veterinary Services (PVS tool) – to assist Veterinary Services to establish their current level of performance, to identify gaps and weaknesses in their ability to comply with OIE international standards and to develop strategies to improve performance. The PVS tool defines effective Veterinary Services as those that have four fundamental components:

– the human, physical and financial resources to attract resources and retain professionals with technical and leadership skills

– the technical authority and capability to address current and new issues, including prevention and control of biological disasters, based on scientific principles

– sustained interaction with stakeholders in order to stay on course and carry out relevant joint programmes and services

– the ability to access markets through compliance with existing standards and the implementation of new disciplines such as the harmonisation of standards, equivalence and zoning (17).

Under each of these four fundamental components, six to twelve critical competencies have been elaborated to enable countries to establish the current level of performance of their Veterinary Services based on performance ratings ranging from level one (low performance) to level five (high performance). Twelve of the countries that experienced HPAI outbreaks during the period covered by this study had assessed their Veterinary Services immediately after the outbreak using the OIE PVS tool. The results of the evaluations of these 12 countries (country names withheld to maintain confidentiality – eight developing countries and four least developed countries) were analysed to ascertain the association between the success of AI control measures and 15 critical competencies (drawn from across the four fundamental components of the PVS tool [17]). The areas evaluated were:

– staffing (veterinarians)
– staffing (veterinary paraprofessionals)
– professional competencies of veterinarians and veterinary paraprofessionals
– continuing education
– stability of structures and sustainability of policies
– emergency funding
– capital investment
– veterinary laboratory diagnosis
– epidemiological surveillance
– early detection and emergency response
– disease prevention, control and eradication
– veterinary medicines and biologicals
– transparency
– compartmentalisation
– zoning.

More specifically, the study looked at the association between HPAI control data and the capacity of Veterinary Services to do the following:

a) ensure that Veterinary Services are staffed appropriately, i.e. define the needs of the service, draw up appropriate job descriptions and have procedures that ensure all veterinary positions are filled by professionals who have appropriate university-level qualifications

b) establish procedures for the appointment of veterinary paraprofessionals and ensure that technical positions are occupied by staff with the requisite technical knowledge

c) ensure that staff have the skills and knowledge to carry out their functions

d) maintain and improve the competence of the Veterinary Services personnel in terms of relevant information and understanding, measured in terms of the implementation of a training programme

e) implement and sustain policies over time

f) access extraordinary financial resources in order to respond to emergency situations or emerging issues

g) access funding for basic and additional investments (material and non-material) that lead to a sustained improvement in the Veterinary Services operational infrastructure

h) identify and record pathogenic agents, including those relevant for public health, that can adversely affect animals and animal products

i) determine, verify and report on the sanitary status of the animal populations under their mandate

j) detect and respond rapidly to a sanitary emergency such as a significant disease outbreak or food safety emergency

k) actively perform actions to prevent, control or eradicate OIE-listed diseases and/or to demonstrate that the country or a zone are free of relevant diseases

l) regulate veterinary medicines and veterinary biologicals, i.e. the authorisation, registration, import, production, labelling, distribution, sale and use of these products

m) notify the OIE of the sanitary status of their country and inform them of other relevant matters in accordance with established procedures

n) establish and maintain disease-free zones, as necessary and in accordance with the criteria established by the OIE

o) establish and maintain disease-free compartments as necessary and in accordance with the criteria established by the OIE.

Statistical data analysis

For each country, GDP, AGDP, % AGDP, GDP per capita, GNI, HDI, poultry density, and PVS evaluation scores were compared to HPAI control data to determine association by statistical analysis. The data were subjected to linear regression statistical analysis (Epi Info™ Version 3.5.3, Centers for Disease Control and Prevention, USA) to evaluate the *R* value (correlation coefficient) and R^2 value (coefficient of determination). All the *R* values were subjected to a test of significance to find out the significant *R* values at 5% level. *R* value denotes the strength of the correlation of the tested parameters with HPAI control data, while R^2 value indicates the fraction of variance that is shared between them.

High-pathogenicity avian influenza control data for OECD countries were compared with data from non-OECD countries. Student's *t* test was used to analyse data on the number of outbreaks, outbreak duration and eradication time, and the Chi-square test (Epi Info™ Version 3.5.3) was used to compare mortality and culling rates.

Results

Poultry density and economic indicators

Linear regression analysis of HPAI control data in poultry (2002 to 2010) with poultry density and economic indicators (GDP, AGDP, % AGDP, GDP per capita, GNI and HDI) are presented in Table I.

Poultry density of least developed countries showed significance ($p < 0.05$) for outbreak duration ($R = 0.92$), length of eradication time ($R = 0.92$) and number of cases ($R = 0.93$). This indicates a strong positive linkage, i.e. the higher the poultry density, the longer the duration of the disease, the longer the length of time to eradicate the disease, and the greater the number of cases. The R^2 values for these parameters were more than 0.85, indicating that more than 85% of the variability in outbreak duration, eradication time and number of outbreaks could be explained by the poultry density. Mortality and culling rates of least developed countries showed no correlation with poultry density.

The poultry density of developing/transition and developed countries showed insignificant *R* values for all HPAI control data, indicating that there was no correlation between them.

All *R* values for GDP, AGDP, % AGDP, GDP per capita, GNI and HDI were non-significant, indicating there was no significant correlation between HPAI control data and these economic indicators.

A comparison of the mean number of outbreaks, the mean mortality and culling rates, the mean outbreak duration and the mean eradication time in OECD countries and non-OECD countries is presented in Table II. There was

Table I
Linear regression comparison of high-pathogenicity avian influenza control data in poultry (2002 to 2010) with poultry density and economic indicators

Country classification	Variables	HPAI control data: Outbreak duration (days)		Eradication time (days)		Mortality rate (no./100,000 birds)		Culling rate (no./100,000 birds)		No. of outbreaks	
		R value	R^2 value	*R* value	R^2 value	*R* value	R^2 value	*R* value	R^2 value	*R* value	R^2 value
All countries	Poultry density	0.10	0.01	0	0	0.20	0.04	0.22	0.05	0.10	0.01
(*n* = 60)	GDP	– 0.28	0.08	0.20	0.04	– 0.10	0.01	0.17	0.03	– 0.20	0.04
	AGDP	0.14	0.02	0	0	0.10	0.01	0.24	0.06	0.17	0.03
	% AGDP	– 0.10	0.01	0.14	0.02	– 0.24	0.06	0.28	0.08	– 0.20	0.04
	GDP per capita	– 0.39	0.15	– 0.39	0.15	0	0	0.63	0.40	– 0.58	0.34
	GNI	0.20	0.04	0.20	0.04	– 0.10	0.01	0.22	0.05	– 0.24	0.06
	HDI	0.14	0.02	– 0.14	0.02	0	0	0	0	0	0
Least developed	Poultry density	0.92*	0.86	0.92*	0.85	0	0	0	0	0.93*	0.87
countries**	GDP	0	0	0	0	0.26	0.07	0	0	0	0
(*n* = 12)	AGDP	0	0	0	0	0.24	0.06	0.10	0.01	0	0
	% AGDP	– 0.26	0.07	– 0.30	0.09	– 0.10	0.01	– 0.17	0.03	– 0.24	0.06
	GDP per capita	– 0.10	0.01	– 0.10	0.01	0	0	0.10	0.01	– 0.20	0.04
	GNI	0.22	0.05	0	0	0.14	0.02	0	0	0.17	0.03
	HDI	0.17	0.03	0.22	0.05	0.10	0.01	0.10	0.01	0	0
Developing	Poultry density	– 0.14	0.02	– 0.14	0.02	– 0.14	0.02	0	0	– 0.10	0.01
countries***	GDP	0	0	0	0	0.10	0.01	0.14	0.02	0.10	0.01
(*n* = 33)	AGDP	0	0	0	0	0.10	0.01	0.14	0.02	0.10	0.01
	% AGDP	– 0.24	0.06	– 0.17	0.03	0	0	0.10	0.01	– 0.17	0.03
	GDP per capita	– 0.14	0.02	– 0.14	0.02	– 0.17	0.03	0.79	0.63	– 0.14	0.02
	GNI	0.14	0.02	0.10	0.01	– 0.24	0.06	– 0.28	0.08	0.14	0.02
	HDI	– 0.28	0.08	0	0	– 0.14	0.02	0	0	– 0.22	0.05
Developed	Poultry density	0.10	0.01	– 0.10	0.01	0	0	0.24	0.06	– 0.20	0.04
countries****	GDP	0	0	0	0	0.20	0.04	0.14	0.02	0.20	0.04
(*n* = 15)	AGDP	0.14	0.02	0.14	0.02	0.10	0.01	0.10	0.01	0	0
	% AGDP	– 0.10	0.01	– 0.10	0.01	0	0	– 0.10	0.01	0.10	0.01
	GDP per capita	– 0.26	0.07	– 0.26	0.07	0.14	0.02	0	0	– 0.17	0.03
	GNI	0.28	0.08	– 0.24	0.06	0.10	0.01	– 0.14	0.02	0.28	0.08
	HDI	– 0.14	0.02	0.22	0.05	– 0.10	0.01	0.28	0.08	– 0.24	0.06

% AGDP: percentage of agriculture contributed to GDP
AGDP: agricultural gross domestic product
GDP: gross domestic product
GNI: gross national income
HDI: human development index
HPAI: high-pathogenicity avian influenza
* Significant at $p < 0.05$
** Afghanistan, Bangladesh, Benin, Bhutan, Burkina Faso, Cambodia, Djibouti, Lao People's Democratic Republic, Myanmar, Niger, Sudan and Togo
*** Albania, Azerbaijan, Cameroon, Chile, People's Republic of China, Côte d'Ivoire, Egypt, Ghana, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Jordan, Kazakhstan, Republic of Korea, Democratic People's Republic of Korea, Kuwait, Malaysia, Nigeria, Nepal, Pakistan, Palestinian territories, Russia, Saudi Arabia, Serbia, South Africa, Thailand, Turkey, Ukraine, Vietnam and Zimbabwe
**** Belgium, Canada, Czech Republic, Denmark, France, Germany, Hungary, Japan, Netherlands, Poland, Romania, Spain, Sweden, United Kingdom and United States

Table II
Comparison of the high-pathogenicity avian influenza control data of OECD countries (*n* = 18) with non-OECD countries (*n* = 42)

Group	Mean outbreak duration (days)	Mean eradication time (days)	Mean no. of outbreaks	Mean mortality rate (no./100,000 birds)	Mean culling rate (no./100,000 birds)
OECD countries***	86.97*	176.97*	19.31*	12.36**	924.04**
Non-OECD countries****	177.33*	267.82*	65.39*	27.70**	236.35**

OECD: Organisation for Economic Co-operation and Development
* Significant at $p < 0.05$ by Student's *t* test
** Significant at $p < 0.05$ by Chi-square test
***Belgium, Canada, Chile, Czech Republic, Denmark, France, Germany, Hungary, Israel, Japan, Republic of Korea, Netherlands, Poland, Spain, Sweden, Turkey, United Kingdom and United States
****Afghanistan, Albania, Azerbaijan, Bangladesh, Benin, Bhutan, Burkina Faso, Cambodia, Cameroon, People's Republic of China, Côte d'Ivoire, Djibouti, Egypt, Ghana, Hong Kong, India, Indonesia, Iran, Iraq, Jordan, Kazakhstan, Democratic Republic of Korea, Kuwait, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Niger, Nigeria, Pakistan, Palestinian territories, Romania, Russia, Saudi Arabia, Serbia, South Africa, Sudan, Thailand, Togo, Ukraine, Vietnam and Zimbabwe

significant difference between the means, indicating that OECD countries had shorter outbreaks, shorter eradication times and fewer outbreaks than non-OECD countries. Also, OECD countries had lower mortality rates and higher culling rates than non-OECD countries.

Performance of Veterinary Services

Linear regression analysis of PVS tool critical competencies and HPAI control data is presented in Table III. The significant *R* values ($p < 0.05$) and R^2 values showed that there was significant correlation between HPAI data and certain critical competencies, as follows:

a) negative correlation of the staffing of Veterinary Services (veterinarians and other professionals) with HPAI eradication time, mortality rate, culling rate and number of outbreaks, i.e. as the appropriate staffing of the Veterinary Services by veterinarians increased, the time for eradication of AI, the mortality and culling rate associated with HPAI outbreaks and the occurrence of outbreaks decreased

b) negative correlation of the staffing of Veterinary Services (veterinary paraprofessionals) with mortality rate, i.e. when the number of technically qualified personnel increased, the mortality rate decreased

c) negative correlation of the professional competencies of veterinarians with mortality rate, i.e. as veterinary practices and attitudes improved and veterinary knowledge increased, the mortality rate due to the disease decreased

d) negative correlation of continuing education with mortality rate, i.e. as the competence of personnel in Veterinary Services increased through relevant training programmes, there was a decrease in the mortality rate

e) negative correlation of emergency funding with HPAI eradication time, i.e. when the financial resources of the Veterinary Services increased, there was a decrease in the eradication time of AI

f) negative correlation of veterinary laboratory diagnosis with HPAI eradication time and number of outbreaks, i.e. as the capacity to perform laboratory-based diagnosis of

Table III
Linear regression analysis of high-pathogenicity avian influenza control data with the critical competencies evaluated in the OIE Tool for the Evaluation of Performance of Veterinary Services

OIE PVS tool critical competencies	HPAI control data							
	HPAI eradication time (days)		Mortality rate (no./100,000 birds)		Culling rate (no./100,000 birds)		No. of HPAI outbreaks	
	R value	R^2 value	*R* value	R^2 value	*R* value	R^2 value	*R* value	R^2 value
Staffing (veterinarians and other professionals)	– 0.83*	0.70	– 0.57*	0.33	– 0.86*	0.74	– 0.83*	0.69
Staffing (veterinary paraprofessionals and other)	– 0.30	0.09	– 0.81*	0.67	– 0.24	0.06	– 0.28	0.08
Professional competencies of veterinarians	0	0	– 0.65*	0.43	0.10	0.01	– 0.22	0.05
Competencies of veterinary paraprofessionals	– 0.37	0.14	– 0.33	0.11	– 0.38	0.15	– 0.22	0.05
Continuing education	– 0.28	0.08	– 0.82*	0.68	– 0.43	0.19	– 0.20	0.04
Technical independence	– 0.20	0.04	– 0.10	0.01	– 0.34	0.12	– 0.31	0.10
Stability of structures and sustainability of policies	– 0.43	0.19	– 0.14	0.02	– 0.14	0.02	0	0
Coordination capability of Veterinary Services	– 0.26	0.07	– 0.10	0.01	– 0.28	0.08	– 0.28	0.08
Operational funding	0	0	– 0.14	0.02	– 0.17	0.03	– 0.17	0.03
Emergency funding	– 0.58*	0.34	– 0.10	0.01	– 0.26	0.07	– 0.40	0.16
Capital investment	– 0.31	0.10	0	0	– 0.34	0.12	– 0.47	0.23
Veterinary laboratory diagnosis	– 0.46	0.22	– 0.10	0.01	– 0.45	0.21	– 0.72*	0.53
Risk analysis	0	0	– 0.14	0.02	– 0.17	0.03	0.17	0.03
Quarantine and border security	0	0	0.10	0.01	0.14	0.02	0.10	0.01
Epidemiological surveillance	– 0.57*	0.32	– 0.26	0.07	– 0.48	0.24	– 0.45	0.21
Early detection and emergency response	0.20	0.04	0	0	– 0.24	0.06	– 0.38	0.15
Veterinary medicines and veterinary biologicals	0	0	– 0.40	0.16	– 0.64*	0.41	– 0.60*	0.37
Animal identification and movement control	– 0.20	0.04	– 0.31	0.10	– 0.14	0.02	0	0
Transparency	– 0.10	0.01	– 0.34	0.12	– 0.66*	0.44	– 0.59*	0.35
Zoning	0.24	0.06	– 0.26	0.07	– 0.20	0.04	0.38	0.15
Compartmentalisation	0.17	0.03	– 0.20	0.04	0	0	0.20	0.04
Disease prevention, control and eradication	– 0.80*	0.64	0.24	0.06	– 0.50*	0.25	– 0.86*	0.74

HPAI: high-pathogenicity avian influenza
PVS: Performance of Veterinary Services
*Significant at $p < 0.05$

pathogenic agents increased, there was a decrease in the eradication time and fewer outbreaks

g) negative correlation of epidemiological surveillance with HPAI eradication time, i.e. when there was more active and passive surveillance, there was a decrease in the time taken to eradicate HPAI

h) negative correlation of veterinary medicines and veterinary biologicals with culling rate and number of outbreaks, i.e. when the Veterinary Services had a greater capacity to regulate the registration, import, production, labelling, distribution, sale and use of veterinary medicines and biologicals, there was a reduction in the culling rate and number of outbreaks

i) negative correlation of transparency with culling rate and number of outbreaks, i.e. when the capacity of Veterinary Services to provide regular animal health status reports to the OIE increased, there was a decrease in the culling rate and number of outbreaks

j) negative correlation of disease prevention, control and eradication measures with HPAI eradication time, culling rate and number of outbreaks, i.e. as the Veterinary Services increased the number of prevention, control and eradication programmes for OIE-listed diseases, there was a decrease in HPAI outbreaks, eradication time and culling rate.

Discussion

Poultry density

High-density poultry farms located in least developed countries were associated with longer outbreaks, longer eradication times and an increased incidence of outbreaks. A high density of poultry facilitates the rapid transmission of the virus between birds and between farms, and could lead to environmental persistence of the virus for a longer period of time. This study corroborated earlier findings in some developing countries. In Vietnam, for example, medium poultry density was found to be a risk factor for HPAI outbreaks (8). Similarly, high poultry density was found to be associated with HPAI outbreaks in Thailand (12) and Hong Kong (9). The virus can move from bird to bird and farm to farm far more easily in a high poultry density zone than in a low density area, especially if between-farm biosecurity is poor. However, in developed and developing/transition countries, high poultry density was not associated with an increase in the number or duration of HPAI outbreaks or in eradication times. This suggests that in such countries other components of poultry management, such as better biosecurity and veterinary care, compensated for the increased poultry density and prevented increasing transmission and spread of HPAI viruses.

Economic development indicators

There was no significant correlation between GDP, AGDP, % AGDP, GDP per capita, GNI and HDI with HPAI control data. This suggests that several other factors, such as environment, ecology, poultry production systems and implementation of effective control programmes, may influence the occurrence and control/eradication of the disease in a country (5). Continuous or intermittent HPAI outbreaks have been reported in high-GDP countries such as China, Germany, India, Japan, the Republic of Korea, Malaysia and Russia, even though abundant resources are devoted to disease surveillance and biosecurity in these countries. In medium-GDP countries, such as Bangladesh, Egypt, Indonesia and Vietnam, the disease is prevalent and is endemic in nature. In contrast, Afghanistan, Benin and Bhutan, which are low-GDP countries, have only ever experienced occasional small outbreaks of HPAI. This indicates that the virus can cause disease in a country irrespective of its GDP and that control/eradication is complex and influenced by multiple factors. However, the OECD countries that have systems of economic development and governance which favour transparency, economic growth and financial stability had significantly fewer HPAI outbreaks, shorter outbreaks, shorter eradication times, lower mortality rates and higher culling rates than non-OECD countries.

Performance of Veterinary Services

If a country's Veterinary Services perform well it has a better chance of controlling and preventing HPAI outbreaks. Veterinary Services can only carry out their functions effectively if they have:

– appropriately qualified staff and a sufficient number of posts

– professionally competent staff who have regular access to continuous education and relevant training

– sound financial resources for continued operation of the Veterinary Services

– rapid laboratory-based diagnosis of pathogenic agents

– continuous epidemiological surveillance for various diseases and reporting of disease status to the OIE

– effective regulation of veterinary medicines and biologicals

– increased prevention, control and eradication measures for OIE-listed diseases.

Veterinary Services must perform optimally in all these areas if they are to implement effective control measures and prevent AI. If there is a decrease in the level of critical competencies, then there is the potential for outbreaks to become prolonged and difficult to eradicate.

The role of Veterinary Services is recognised as a 'global public good' by the World Bank. Veterinary Services are involved in the provision of animal health services, and this requires close working partnerships between veterinarians, veterinary assistants, and livestock and poultry farmers. When Veterinary Services fail in a single country, this creates a threat to the entire world. Animal disease outbreaks pose more of a problem when they occur in countries that have no effective surveillance and no preventive animal health network (1).

Veterinary Services at the national level play a key role in combating HPAI outbreaks and countries should evaluate their Veterinary Services using the OIE PVS tool or similar assessment tool to identify gaps and weaknesses in their ability to comply with OIE international standards on animal health. Once countries know how they are currently performing they can decide how best to reinforce their national preparedness plans for AI control in line with international standards and guidelines. They can also ensure that they strengthen their Veterinary Services in ways which will facilitate the early detection of HPAI outbreaks and the implementation of efficient control measures.

Although analysis of GDP, AGDP, % AGPD, GDP per capita, GNI and HDI did not indicate a direct economic link to HPAI control, the combined results of the OECD and PVS analyses suggest that countries which invested financial and human resources in their Veterinary Services had more effective disease control and preventive measures for HPAI. However, this is not solely a financial issue, but also involves multiple other factors connected to OECD membership, including transparency and good governance. Previously, a close relationship was demonstrated between GDP and public spending on National Prevention Systems for Animal Diseases and Zoonoses (NPS), and further linked livestock density, especially poultry density, and export of animal products in wealthier developing countries to increased levels of spending on NPS (4). Countries that produce and export meat have better veterinary governance and are associated with Veterinary Services that achieve high ratings when their critical competencies are evaluated (J. Commault, OIE unpublished data, 2011). In addition, the GDP per capita was positively linked to high-performing Veterinary Services. It should be noted, however, that a high GDP is not always sufficient for Veterinary Services to perform well in all areas: some high-GDP countries do not have high-performing Veterinary Services (J. Commault, OIE unpublished data, 2011). However, a country with a high GDP which is also transparent and well-governed is more likely to have good Veterinary Services and will therefore be better placed to control HPAI outbreaks.

Conclusions

A high poultry density in least developed countries was associated with increased duration of HPAI outbreaks, a longer time to eradicate the disease and a greater number of cases. Direct economic indicators such as GDP, AGDP, % AGDP, GDP per capita, GNI and HDI do not show a significant association with HPAI control data, but an indirect indicator of economic development (i.e. OECD membership) was positively linked to fewer HPAI outbreaks, shorter outbreak duration and eradication time, and a low mortality rate and high culling rate. Several of the core critical competencies that are evaluated by the OIE PVS tool have a significant association with improved HPAI control. For example, the disease is more effectively controlled when Veterinary Services are appropriately staffed, veterinarians have a high level of competence, and staff have regular opportunities to update their skills. Similarly, HPAI control is better in countries whose Veterinary Services have the capacity to access financial resources, carry out epidemiological surveillance, perform laboratory-based diagnosis, maintain transparency, and implement disease prevention and control measures. A country with a high level of competence in these areas can establish a good network of disease surveillance and implement control measures to tackle HPAI outbreaks. Such a network can be extended to LPNAI, Newcastle disease and other poultry diseases. Establishing the current level of performance of the Veterinary Services in a country and improving its level of advancement by addressing the deficiencies will help in implementing more effective measures against AI in control programmes. In total, the data imply that countries which are transparent, have good governance and provide adequate funding for the development and maintenance of efficiently performing Veterinary Services have better control of HPAI.

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L'influence des indicateurs économiques, de la densité des populations de volailles et des performances des Services vétérinaires sur les résultats de la lutte contre l'influenza aviaire hautement pathogène chez les volailles

G. Pavade, L. Awada, K. Hamilton & D.E. Swayne

Résumé

L'influenza aviaire hautement pathogène (IAHP) et l'influenza aviaire faiblement pathogène (IAFP) à déclaration obligatoire sont des maladies dont la survenue doit faire l'objet d'une notification à l'Organisation mondiale de la santé animale (OIE). La réaction des pays confrontés à un foyer d'influenza aviaire varie d'un pays à l'autre, en fonction de leur situation économique, de leurs capacités de diagnostic et de divers autres facteurs. Les auteurs présentent les résultats d'une étude visant à vérifier la corrélation existant entre les données de la lutte contre l'IAHP dans un pays et la densité des populations de volailles, les performances des Services vétérinaires ainsi que divers indicateurs économiques (produit intérieur brut, produit intérieur brut agricole, revenu national brut, indice de développement humain et classement au sein de l'Organisation de coopération et de développement économiques [OCDE]). Les résultats de l'étude montrent que l'accroissement de la densité de volailles dans les pays les moins développés s'accompagne d'une augmentation du nombre et de la durée des foyers d'IAHP et de délais d'éradication plus longs. Aucune corrélation significative n'a été constatée entre les données de la lutte contre l'IAHP et l'un ou l'autre des indicateurs économiques, à l'exception de l'appartenance à l'OCDE. Dans les pays membres de l'OCDE, c'est-à-dire ceux à fort revenu et dotés de transparence et d'une bonne gouvernance, les foyers d'IAHP étaient significativement moins nombreux et duraient moins longtemps, les délais d'éradication étaient plus courts, les taux de mortalité étaient plus faibles et le pourcentage de volailles abattues était plus élevé que dans les pays non membres de l'OCDE. De plus, les pays dotés de Services vétérinaires efficaces et efficients (d'après le relevé de leurs performances effectué au moyen de l'Outil de l'OIE pour l'évaluation des performances des Services vétérinaires [Outil PVS]) obtenaient de meilleurs résultats dans la lutte contre l'IAHP.

Mots-clés

Éradication – Indicateur économique – Influenza aviaire – Lutte contre les maladies – OCDE – Outil PVS de l'OIE – Services vétérinaires.

■

Influencia de los indicadores económicos, la densidad de animales y la eficacia de los Servicios Veterinarios sobre la lucha contra la influenza aviar altamente patógena en aves de corral

G. Pavade, L. Awada, K. Hamilton & D.E. Swayne

Resumen

La influenza aviar altamente patógena (IAAP) y la influenza aviar levemente patógena (IALP) de declaración obligatoria en las aves de corral son enfermedades que es imperativo notificar a la Organización Mundial de Sanidad

Animal (OIE). Los países aportan una respuesta diferente a los brotes de influenza aviar (IA) según cuáles sean, entre otros factores, su situación económica y su capacidad de diagnóstico. Los autores describen un estudio encaminado a desentrañar la relación significativa entre los datos de la lucha contra la IAAP y la densidad de aves de corral de un país, la eficacia de sus Servicios Veterinarios y sus indicadores económicos (producto interior bruto, producto interior bruto agrícola, ingreso nacional bruto, índice de desarrollo humano y pertenencia o no a la Organización de Cooperación y Desarrollo Económicos [OCDE]). Los resultados indican que, en el caso de los países menos adelantados, a medida que se incrementa la densidad de aves de corral aumentan el número de botes de IAAP, su duración y el tiempo necesario para erradicar la enfermedad. No se observó ninguna correlación significativa entre la lucha contra la IAAP y uno u otro indicador económico, exceptuando la pertenencia a la OCDE. Los Países Miembros de esta Organización, que poseen una economía con un elevado nivel de renta y gozan de transparencia y buen gobierno, sufrían brotes de IAAP más cortos y en número significativamente menor, lograban erradicarlos en menos tiempo y presentaban tasas de mortalidad más bajas e índices de sacrificio sanitario más elevados que los países no pertenecientes a la OCDE. Además, los países que contaban con Servicios Veterinarios eficaces (a juzgar por la puntuación obtenida al ser analizados con la herramienta de la OIE para evaluar la eficacia de los Servicios Veterinarios) instauraban mejores medidas de control de la IAAP.

Palabras clave
Control – Erradicación – Herramienta PVS de la OIE – Indicador económico – Influenza aviar – OCDE – Servicios Veterinarios.

References

1. Angot J.L. (2009). – Surveillance and control of imported animal diseases. Role of the OIE and Veterinary Services. *Bull. Acad. nat. Méd.*, **193** (8), 1869–1870.

2. Angot J.L. (2009). – The governance of Veterinary Services and their role in the control of avian influenza. *In* Avian influenza (T. Mettenleiter, ed.). *Rev. sci. tech. Off. int. Epiz.*, **28** (1), 397–400.

3. Central Intelligence Agency (2011). – The World Factbook. Available at: www.cia.gov/library/publications/the-world-factbook/ (accessed on 31 January 2011).

4. Civic Consulting (2009). – Cost of national prevention systems for animal diseases and zoonoses in developing and transition countries. Report to the World Organisation for Animal Health (OIE). OIE, Paris.

5. Fang L.-Q., de Vlas S.J., Liang S., Looman C.W.N., Gong P., Xu B., Yan L., Yang H., Richardus J. H. & Cao W.C. (2008). – Environmental factors contributing to the spread of H5N1 avian influenza in mainland China. *PLoS ONE*, **3** (5), e2268.doi:10.1371/journal.pone.0002268.

6. Food and Agriculture Organization of the United Nations (2011). – Global livestock production and health atlas (GLiPHA). Available at: kids.fao.org/glipha/ (accessed on 20 March 2011).

7. Food and Agriculture Organization of the United Nations (2011). – Time series and cross sectional data relating to food and agriculture for some 200 countries. Available at: faostat.fao.org/site/291/default.aspx.

8. Henning J., Pfeiffer D.U. & Vu L.T. (2009). – Risk factors and characteristics of H5N1 highly pathogenic avian influenza (HPAI) post-vaccination outbreaks. *Vet. Res.*, **40**, 15.

9. Kung N.Y., Morris R.S., Perkins N.R., Sims L.D., Ellis T.M., Bissett L., Chow M., Shortridge K.F., Guan Y. & Peiris M.J.S. (2007). – Risk for infection with highly pathogenic influenza A virus (H5N1) in chickens, Hong Kong, 2002. *Emerg. infect. Dis.*, **13** (3), 412–418.

10. McLeod A. (2008). – The economics of avian influenza. *In* Avian influenza (D.E. Swayne, ed.). Blackwell Publishing, Ames, Iowa, 537–560.

11. Organisation for Economic Co-operation and Development (OECD) (2011). – OECD current membership. Available at: www.oecd.org/pages/0,3417,en_36734052_36761800_1_1_1_1_1,00.html (accessed on 19 September 2011).

12. Tiensin T., Chaitaweesub P., Songserm T., Chaisingh A., Hoonsuwan W., Buranathai C., Parakamawonsa T., Premashthira S., Amonsin A., Gilbert M., Nielen M. & Stegeman A. (2005). – Highly pathogenic avian influenza H5N1, Thailand, 2004. *Emerg. infect. Dis.*, **11** (11), 1664–1672.

13. United Nations Development Programme (UNDP) (2011). – Human development index. Available at: hdr.undp.org/en/statistics/hdi/ (accessed on 31 August 2011).

14. United Nations Statistics Division (UNSTATS) (2010). – Selected economic and other groupings of regions. Available at: unstats.un.org/unsd/methods/m49/m49regin.htm (accessed on 16 June 2011)

15. World Bank (2011). – Gross national income (GNI) per capita, purchasing power parity (PPP) (current international $). Available at: data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD (accessed on 02 September 2010).

16. World Organisation for Animal Health (OIE) (2010). – Avian influenza. *In* Terrestrial Animal Health Code. OIE, Paris, 526–543. Also available at: www.oie.int/en/international-standard-setting/terrestrial-code/access-online/ (accessed on 10 May 2011).

17. World Organisation for Animal (OIE) (2010). – The OIE Tool for the Evaluation of Performance of Veterinary Services. Available at: www.oie.int/en/support-to-oie-members/pvs-evaluations/oie-pvs-tool/ (accessed on 24 June 2011).

18. World Organisation for Animal Health (OIE) (2011). – Handistats II – Animal health data prior to 2005. Available at: web.oie.int/wahis/public.php?page=home (accessed on 10 January 2011).

19. World Organisation for Animal Health (OIE) (2011). – World Animal Health Information Database. Animal diseases 2005 – present. Available at: web.oie.int/wahis/public.php?page=home (accessed on 15 February 2011).