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Horse owners'/managers' perceptions about effectiveness of biosecurity measures based on their experiences during the 2007 equine influenza outbreak in Australia

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Abstract

Following the first ever equine influenza outbreak in Australia in 2007, a study was conducted involving 200 horse owners and managers to determine their perceptions about effectiveness of biosecurity measures and the factors associated with these perceptions. Face-to-face interviews were conducted with horse owners/managers to obtain information about their perceptions of the effectiveness of biosecurity practices, their sources of information about infection control during the outbreak and their horse industry involvement. Two outcome variables were created from horse owners' responses to a 17-item question on the perceived effectiveness of various recommended equine influenza biosecurity measures: (a) a binary outcome variable (Low/High biosecurity effectiveness) and (b) a continuous outcome variable (the proportion of the 17 measures considered 'very effective'). These outcomes were used in binomial logistic and linear regression analyses, respectively, to determine factors associated with perceptions of biosecurity effectiveness. Variables with a *p*-value <0.05 in multivariable models were retained in the final models.

The majority (83%) of the 200 horse owners and managers interviewed believed that more than half of the recommended equine influenza biosecurity measures were very effective for protecting their horses from equine influenza infection in the event of a future outbreak. Interviewees that were more likely to judge on-farm biosecurity measures as effective were those who received infection control information from a veterinarian during the outbreak, did not experience equine influenza infection in their horses, and those on small acreage premises (homes with horses on site). Greater levels of preparedness for a future equine influenza outbreak and greater interest in information about infection control were associated with a better perception about effectiveness of biosecurity measures.

This study identified factors associated with horse owners' and managers' perception of effectiveness of biosecurity measures. These findings should be considered in the design of infection control programs.

Keywords:

Biosecurity practices

Equine

Equine influenza

Owner perceptions

Behaviour change

Regression analysis

1. Introduction

In late August 2007, Australia experienced its first ever outbreak of equine influenza, a highly contagious respiratory disease affecting all members of the Equidae family. The outbreak followed the importation of infected horses from Japan and subsequent escape of the virus from the Eastern Creek quarantine facility in Sydney, New South Wales (NSW) (Callinan, 2008). On 24 August 2007, initial laboratory confirmation was received that horses at a large equestrian facility in central Sydney were infected with equine influenza virus. Over a period of 4 months, the virus spread through major parts of the state of NSW and into south-eastern Queensland. The last case was detected in Queensland on 25 December 2007. In order to control, contain and eradicate the disease, the government implemented outbreak control measures, including movement restrictions, vaccination, quarantining of properties and issuing of biosecurity guidelines (NSW DPI, 2007a; DEEDI, 2011). Biosecurity guidelines included personal hygiene, equipment hygiene and access control measures and were based on expert advice, as at the time of the outbreak, no research had been conducted into the effectiveness of on-farm biosecurity measures for equine influenza control. This study was conducted to investigate horse owners' sources of biosecurity information and the factors associated with the perception of biosecurity effectiveness.

A large body of literature supports a range of theories for human behaviour modification, particularly regarding health protective behaviours. A recent review by Bish and Michie (2010) examined 26 papers and concluded that a greater belief in the effectiveness of recommended behaviours to protect against a disease is an important predictor of human behaviour during pandemics. In the United States trends in general biosecurity practices on equine operations have been monitored since 1998 (APHIS, 2007), in contrast, no such data is available in Australia. In a study conducted with 2760 Australian horse owners during the 2007 equine influenza outbreak (Taylor et al., 2008; Taylor and Agho, 2009) the majority of respondents reported practicing at least some access control and personal hygiene measures to protect their horses from equine influenza, and most of these respondents believed that these measures were effective. Further research identified that Australian horse owners who believed in the effectiveness of their current on-farm hygiene measures were more likely to demonstrate a high level of compliance with general recommended biosecurity measures (Schemann et al., 2010). The aim of this study was to investigate information sources used by horse owners and managers during the 2007 equine influenza outbreak in Australia, and the factors associated with perceptions about effectiveness of the recommended on-farm biosecurity measures. This information is important for animal health authorities in their efforts to influence voluntary compliance with biosecurity policies, through ensuring that extension activities are appropriately focused. Specific knowledge regarding the factors that influence perceptions of biosecurity effectiveness can inform the design of infection control programmes, whether they be for preventing future exotic disease incursions or controlling endemic diseases.

2. Materials and methods

2.1. Questionnaire design and sampling

Horse premises located in regions of NSW considered ‘at risk’ during the 2007 equine influenza outbreak were selected using computer generated pseudo-random numbers from a dataset of premises tested for equine influenza supplied by the NSW Department of Primary Industries (DPI). ‘At risk’ regions were defined as restricted areas and special restricted areas according to the risk-based zoning system implemented by the NSW DPI in its Equine Influenza Protection Plan (NSW DPI, 2007b). A detailed description of the study design, sample size calculation, inclusion and exclusion criteria, and the enrolment process for this study is provided in Firestone et al. (2011). Briefly, a total of 270 horse owners and managers were asked to participate in the study by a personally addressed letter and up to 3 follow-up telephone calls to assess eligibility. To meet the selection criteria for a concurrently conducted case-control study, participants were randomly selected from lists of premises that tested positive and premises that tested negative for equine influenza infection within the first month of the outbreak (Firestone et al., 2011). Of the 270 premises selected, 38 were deemed ineligible for the concurrently conducted study (Firestone et al., 2011), whilst the owners and/or managers of another 32 premises declined to participate (13 premises owners and managers who experienced equine influenza in their horses and 19 who did not). Ultimately 200 owners and managers were enrolled, of which 100 were confirmed positive and 100 were confirmed negative for equine influenza during the first month of the outbreak. During the course of the outbreak a further 27 of the premises initially confirmed negative for equine influenza during the first month of the outbreak became positive for equine influenza.

Two interviewers conducted face-to-face structured interviews with enrolled horse owners and managers between July and October 2009 using a piloted questionnaire. The questionnaire contained a total of 61 questions, however only 20 were used in the current study. The remaining 41 questions were used to investigate factors influencing the spread of equine influenza onto horse premises (Firestone et al., 2011). Of the 20 questions, 16 were closed or semi-closed; the remaining 4 questions were open. The questionnaire was designed to obtain information about demographics of participants, the nature of their involvement with horses, their sources of information about infection control during the 2007 equine influenza outbreak, their attitudes towards the effectiveness of biosecurity measures and their attitudes towards a potential future outbreak. The 2 trained interviewers piloted the questionnaire together on 4 horse owners/managers to ensure similar method and response recording. The questionnaire was modified as a result of this feedback to reduce ambiguity. The University of Sydney’s Human Research Ethics Committee approved the study protocol (07-2009/11840).

2.2. Data handling and statistical analysis

All data were entered into a purpose-built Microsoft Access 2007 database (Microsoft Corporation, Redmond, WA, USA).Data cleaning and statistical analyses were conducted using SAS statistical software (release 9.2 © 2002-2008, SAS Institute Inc., Cary, NC, USA).

2.2.1. Outcome variables

Both of the outcome variables used in this study were based on a 17-item question asking interviewees whether they considered each of the measures as ‘very effective’, ‘partially effective’ or ‘not effective’ for protecting their horses from equine influenza infection in a hypothetical scenario of an equine influenza outbreak in the area the following day. The biosecurity measures of interest were based on those recommended by the NSW DPI for equine influenza control during the 2007 outbreak (NSW DPI, 2007a) and are presented in Table 1.

The binary outcome variable for logistic regression analysis (High/Low effectiveness) was derived by categorising respondents into 2 groups based on whether they considered more or less than half of the recommended on-farm biosecurity measures as ‘very effective’. The outcome variable for linear regression analyses reported in this paper was a continuous variable describing the proportion of the 17 biosecurity measures considered to be ‘very effective’ by each horse owner/manager.

2.2.2. Explanatory variables

All 30 explanatory variables investigated in this study are presented in Table 2. The variable ‘Regional cluster’ was derived from research on the 2007 equine influenza outbreak conducted by Cowled et al. (2009), based on an interpolated surface of date of onset of clinical signs, geographic data and location of the infected properties from the NSW DPI data set. The variable ‘Experience with equine influenza infection during the 2007 outbreak’ was created by combining the variable ‘Premises infected with equine influenza during the 2007 outbreak’ with information obtained from infected premises about the most likely source of infection on their premises.

2.2.3. Descriptive analyses

The distributions of explanatory variables were assessed by calculating frequencies and relative frequencies. Further, contingency tables of the explanatory variables for the 2 categories of the biosecurity effectiveness index (‘High effectiveness’ and ‘Low effectiveness’) were evaluated. In addition, descriptive statistics of the continuous outcome were calculated and examined for the categories of the explanatory variables.

2.2.4. Univariable analyses

The unconditional association of each explanatory variable with the binary and continuous outcome variables was assessed in univariable binomial logistic and linear regression analyses, respectively, facilitated by UniLogistic and UniGLM SAS macros (Dhand, 2010). Variables with univariable *p*-value of <0.20 (based on the F-test and likelihood-ratio chi-square test, respectively, for linear and logistic regression) were tested for collinearity in pairs by calculating Spearman’s rank correlation coefficient (ρ) for pairs of ordinal variables or by performing Pearson chi-square test for other pairs of variables. If collinearity existed ($\rho>|0.70|$ or Pearson chi-square $p<0.05$), only the variable of each pair that was more strongly associated with the outcome was retained for further analyses. Additionally, variables were assessed for missing values and excluded from analyses when there were >10% missing values. Excluded variables were retested by including them individually in the final model.

2.2.5. Multivariable analyses

Multivariable binomial logistic and linear regression models were constructed using MultiLogistic and MultiGLM SAS macros, respectively (available at http://sydney.edu.au/vetsci/biostat/macros/) with a manual forward stepwise approach to evaluate the association of explanatory variables with the outcome variables after adjusting for each other. Variables which achieved statistical significance (*p*-value<0.05) in multivariable models were retained in the final model. All other variables eligible for multivariable analyses were retested by adding them individually to the final model. Biologically meaningful 2-way interactions of the explanatory variables in the final model were tested for significance at $p<0.05$. To assess the effect of clustering of observations from the same region, a regional cluster-level random effect term was added to the final model. Potential interviewer bias was assessed by addition of an interviewer-level random effect term to the final model (Hox, 1994). Intra-class correlation (ICC) was then calculated for each random effect using the latent variable approach for the binomial model (Dohoo, 2009). Further, age and gender of participants were considered as potential confounders and forced into the final models to check whether they were in fact having a confounding effect. Outliers and influential observations were evaluated by residual diagnostics using standardised Pearson residuals, leverage and delta-beta values for logistic regression and standardised residuals, leverage and Cook’s distance for linear regression. Goodness-of-fit of the final logistic regression model was assessed using the Hosmer-Lemeshow technique (Hosmer and Lemeshow, 2000).

3. Results

Of the recommended biosecurity measures, not sharing horse gear, controlling who has access to horses and reducing contact with other horses were considered most effective. Cleaning horse gear before use, showering on arrival at the property and disinfecting vehicles entering the property were considered least effective (Table 1).

Just under two thirds of interviewees (63.5%) experienced equine influenza infection in their horses during the 2007 outbreak. A total of 166 horse owners/managers were ranked at the 'High effectiveness' outcome level. The distribution of the 200 horse owners and managers interviewed are presented in Table 3, by age and gender of the respondent, and horse premises type.

During the outbreak, most of the respondents (94%) received equine influenza infection control information from the NSW DPI followed by a private veterinarian (75%), other horse owners (71%), sporting associations (52%) and the Australian Horse Industry Council (24%). The most common information medium used was the internet (79%), followed by word of mouth (77%) and the general media: TV (60%), newspaper (50%) and radio (49%).

3.1. Univariable binomial logistic regression analyses for High biosecurity effectiveness

A total of 11 variables were unconditionally associated with the perception of biosecurity effectiveness at the univariable level cut-off *p*-value of <0.20 (Tables 3 and 4). Horse owners who kept horses only for recreation, were involved in horse racing, or who experienced equine influenza infection in their horses were less likely to perceive biosecurity measures as effective. In contrast, greater perceived preparedness for a future outbreak and greater interest in general infection control information was associated with greater perceived effectiveness of biosecurity measures. The variables 'Premises infected with equine influenza during the 2007 outbreak' and 'Experience with equine influenza infection during the 2007 outbreak' were highly correlated ($\rho=|0.86|$). Due to 'Experience with equine influenza infection' having a stronger association with the outcome, only this variable was retained for further analyses. Only one of the variables ('Perceived level of preparedness for a future equine influenza outbreak'), displayed some missing observations (2%), thus was not excluded. A total of ten variables were considered in multivariable analyses.

3.2. Multivariable binomial logistic regression analyses for High biosecurity effectiveness

The final model for High perceived biosecurity effectiveness for protection of horses from equine influenza infection is presented in Table 5. Most importantly, those receiving infection control information from a veterinarian during the 2007 equine influenza outbreak were 5 times more likely to believe the measures to be effective. Interviewees who actually experienced equine influenza infection in their horses during the 2007 outbreak and who believed that the infection spread onto their premises by being carried on the wind were around 7 times less likely to consider biosecurity measures effective, compared to those who did not experience equine influenza infection in their horses. Analysis also revealed that those associated with commercial studs, equestrian centres or riding schools and those on farms were more than 5 times less likely than people associated with small acreage horse premises to deem measures effective (Table 5). Those in the restricted area were 3 times more likely to believe in the effectiveness of biosecurity measures than those in the special restricted area. In addition, people who were generally more interested in infection control were also likely to think that biosecurity measures were effective (Table 5).Two-way interactions among the variables in the final model were not significant. When added to the final model, the variation due to the interviewer-level random effect term effectively equalled zero, hence this effect did not account for any proportion of the total variance. Similarly, when the regional cluster-level random effect term was added to the model, its intra-class correlation accounted for only 0.01% of the total variability, consequently it was not included in the final model. Age and gender of participants were forced into the final model, yet they were not significant and effectively did not change the model estimates. The Hosmer-Lemeshow goodness-of-fit Chi-squared *p*-value=0.74, indicating good overall fit of the model to the observed data. There were a few individual observations with larger residuals, however none of those had large leverage values and all delta-beta values were <1, hence no observations had undue influence on the model (Hosmer and Lemeshow, 2000).

3.3. Univariable linear regression analyses

A total of 9 variables were unconditionally associated with the perception of biosecurity effectiveness (proportion of the 17 biosecurity measures perceived to be 'very effective' by interviewees) at the univariable level cut-off *p*-value of <0.20 (Table 6). Not being involved in horse-racing or not having experienced equine influenza infection in one's horses was positively associated with perceptions of biosecurity effectiveness. Greater perceived preparedness for a future outbreak, greater interest in general infection control information, performing more stringent than usual practices during the 2007 equine influenza outbreak and not feeling vulnerable to a future equine influenza outbreak were also positively associated with greater perceived effectiveness of biosecurity measures. In contrast, being situated in the special restricted area or in the Windsor or Hunter regions as well as not sourcing equine influenza infection control information from a veterinarian during the 2007 outbreak were negatively associated with perceptions of biosecurity effectiveness (Table 6). The variables 'Premises infected with equine influenza during the 2007 outbreak' and 'Experience with equine influenza infection during the 2007 outbreak' displayed high collinearity, however, 'Experience with equine influenza infection during the 2007 outbreak' was not strongly associated with the outcome and hence excluded (*p*-value>0.20). Only 2 of the variables ('Perceived level of preparedness for a future equine influenza outbreak' and 'Perceived level of vulnerability to a future equine influenza outbreak'), displayed some missing observations (2% and 3% respectively), thus were not excluded. In total, 9 variables were considered in multivariable analyses.

3.4. Multivariable linear regression analyses

The final generalised linear model for perception of biosecurity effectiveness for protection of horses from equine influenza infection is presented in Table 7. The most strongly associated variable with perceptions of biosecurity effectiveness was the perceived level of preparedness for a future equine influenza outbreak. Respondents with a greater level of preparedness considered a greater proportion of biosecurity measures to be effective. Having resided in the special restricted area during the 2007 outbreak resulted in the perception of lower effectiveness of biosecurity measures. Analysis also revealed that greater interest in general infection control information was also associated with greater biosecurity effectiveness perceptions. The 2-way interactions among the variables in the final model were not significant. When added to the final model, the variation due to the interviewer-level random effect term accounted for 2% of the total variance. Similarly, when the regional cluster-level random term was added to the model, its intra-class correlation accounted for 1% of the total variability and neither was consequently included in the final model. The variables age and gender of participants were forced into the final model; however they were not significant and in effect did not alter the model estimates. Residuals displayed some left skew but the assumption of homoscedasciticity was approximately met. Some slightly larger residuals were observed, yet all Cook's distance values were <1, so no observations were considered influential (Cook and Weisber, 1982).

4. Discussion

This study was conducted to identify equine influenza infection control information sources used during the 2007 outbreak and the factors associated with horse owners'/managers' perception of effectiveness of biosecurity practices. Analyses were conducted for a binary and a continuous outcome measure in order to assess effectiveness of biosecurity perceptions.

4.1. Infection control information retrieval

Most respondents (94%) received information from the NSW DPI. This finding was unsurprising as the sampling frame of this study was based on the NSW DPI laboratory testing database. The use of the anecdotally popular NSW DPI equine influenza website may explain the unexpectedly high frequency for infection control information sourced via the internet (79%). Following the NSW DPI, the next most common source used was private veterinarians (75%). These results agree with a market research report (Quantum Market Research, 2007) based on telephone interviews with various Australian livestock producers conducted on behalf of Animal Health Australia prior to the equine influenza outbreak in March 2007. The report found that of the 51 Australian horse industry participants, 78% would typically obtain information or advice in relation to animal health and biosecurity from a veterinarian, followed by 31% who obtained information from other sources. The results of our analysis suggest that veterinarians are not just a frequently consulted source of infection control information in general, but are also important sources of information during an acute disease outbreak.

4.2. Factors associated with perceptions of biosecurity effectiveness

Five factors were important for the perception of High biosecurity effectiveness in binomial logistic regression analyses: whether infection control information was received from a veterinarian during the 2007 equine influenza outbreak, whether horses were believed to have become infected due to windborne spread during the 2007 outbreak, the premises type, the control zone in which interviewees resided during the equine influenza outbreak and their level of general interest in infection control. The latter 2 factors were also important for the proportion of measures considered 'very effective' in linear regression analyses.

Better perception about effectiveness of biosecurity measures among those who received infection control information from a veterinarian was unexpected as previous research with UK cattle and sheep farmers had concluded that attitudes towards biosecurity did not appear to be influenced by information sources per se (Heffernan et al., 2008). The UK study found that veterinarians were a primary source of information for cattle and sheep farmers, however it hypothesised that given the infrequency of contact between farmers and veterinarians, this contact was unlikely to result in behavioural change during an outbreak situation (Heffernan et al., 2008). On the other hand, our finding that veterinarians are important information providers suggests that contact and information exchange between veterinarians and horse owners/managers during an exotic disease outbreak may have contributed to altered perceptions about biosecurity effectiveness. Others (van der Fels-Klerx et al., 2000; Sørensen et al., 2002; Cross et al., 2009) have also observed that veterinary experts are an important source of infection control information for managers as it enables evaluation of the disease risk as well as relevance of control options. In the context of the equine influenza incursion in Australia it can be assumed that equine veterinarians are familiar with equine influenza due to its worldwide distribution and the existence of an Australian equine influenza emergency response plan since 1991(Animal Health Australia, 1991). Biosecurity engagement guidelines reported recently by Kruger et al. (2010) outline several enablers to effective biosecurity engagement between government personnel and horticulturalists such as trust, responsiveness, flexibility, convenience, building networks, commitment and accountability. Many of these enablers are present in the relationship between equine veterinarians and horse owners, potentially catalysing the engagement process. Veterinary clinics are generally well established institutions with long-term key staff such as the practice owner/principal veterinarian. Long-standing service together with demonstrated responsiveness and commitment by veterinarians to routine horse health consultations with owners/managers enables a gradual and continual development of trust. Trust is an important factor in engagement and a pre-existing trustful relationship between veterinarian and horse owner together with the general ability of veterinarians to communicate technical principles to clients in plain language may greatly support the engagement process. Their client's trust and respect may promote veterinarians to act as community champions thereby encouraging or inspiring their clients to change their attitudes and to make behavioural changes. In support of this theory, a study with 43 English and Welsh cattle farmers found that the farmers generally expressed great trust in their veterinarians and that 61% of farmers would implement a disease control program if it was recommended by their private veterinarian (Ellis-Iversen et al., 2010). Further, the visit by a veterinarian during an infectious disease outbreak represents an ideal opportunity for engagement as the time and place is generally convenient for the owner/manager, the veterinarian is communicating face-to-face at the client's property, and clients are likely to be most receptive to biosecurity information during an acute outbreak as the threat of disease is high and their animals are being examined and/or treated. All these arguments may explain why information delivered by a veterinarian is an important factor for the biosecurity effectiveness perceptions of horse owners and managers. The finding suggests that the network among horse owners and equine veterinarians is an already existing network, which should be tapped into for the effective delivery of biosecurity information, especially in an outbreak situation. Additionally, running concurrent educational programs for veterinarians and owners may further raise general biosecurity awareness (Cross et al., 2009). However, there is a possibility of unintended responder bias affecting this association as interviewers were representative of a university veterinary faculty and 1 of the 2 interviewers was a veterinarian, yet we did not observe a significant difference in the responses collected by the 2 interviewers. Bias may also have been incurred through the ongoing veterinarian-client relationship following the equine influenza outbreak, which may have lead to respondents to be more likely to nominate their private veterinarian. To avoid this type of responder bias as much as possible, the question regarding information retrieval during the outbreak was asked following several outbreak recall stimulating exercises (see Firestone et al., 2011 for details).

Another important factor, in addition to whether or not a veterinarian provided infection control information, was whether or not premises became infected with equine influenza during the 2007 outbreak. Not surprisingly, owners and managers of infected horses were less likely to believe in the effectiveness of protective measures. For those who experienced equine influenza infection on their premises during 2007 it was important whether they thought the most likely source of infection was direct (horse to horse) or indirect contact (people, vehicles or fomites) or whether they believed the virus was carried on the wind to their premises. One can assume that the association between the perception of the poor effectiveness of on-farm biosecurity measures and the perception of becoming infected by airborne spread ('on the wind') is linked to having experienced equine influenza infection despite complying as best as possible with the recommended biosecurity measures. Some evidence suggests that local spread facilitated by cough droplets, transmission on fomites and windborne aerosol did occur during this epidemic (Cowled et al., 2009; Davis et al., 2009; Firestone et al., 2011). The result that those who experienced equine influenza infection in their horses in 2007 are now less likely to believe in the effectiveness of biosecurity measures for future outbreaks therefore should be considered in future communication campaigns. Particularly it is recommended that those horse owners and managers in high density horse populated areas, who are more likely to attribute equine influenza infection to windborne spread, are targeted for communication campaigns in future. It may be important that those owners and managers fully understand the differences in disease transmission for different diseases and strains of the same disease and that they are reassured of the effectiveness of recommended measures. Ideally, additional strategies such as face-to-face delivery of information by a trusted communicator should be used to enhance biosecurity engagement with this group.

Premises type was also an important factor for perceptions of biosecurity effectiveness. Interestingly, owners and managers of small acreage homes with horses were most likely to believe that biosecurity measures are effective. Perceptions of lower biosecurity effectiveness of owners and managers at equestrian centres and riding schools may be explained by their inability to control the behaviour of their clients and visitors effectively and the high levels of horse and people movements generally associated with such places. Similarly, commercial stud owners' and managers' perceptions may be influenced by higher exposure to endemic infectious disease associated with movements and experience with legislated import and/or export quarantine procedures. A survey with New Zealand thoroughbred stud managers found that most stud managers were aware of the need for on-farm biosecurity and would practice measures in the face of disease (Rogers and Cogger, 2010). High levels of horse and people movement result in greater risk of disease transmission associated with commercial studs and equestrian centres, hence extension activities should specifically target their owners and managers. An unexpected finding was that people associated with farms were more than 5 times less likely than those on small acreage premises to deem measures effective. This result may be explained by a continuing need for on- and off-property livestock movement making some of the recommended measures impractical in every-day farm life.

The 2 remaining factors associated with High biosecurity effectiveness in logistic regression analysis (the control zone in which respondents were residing during the 2007 outbreak and their level of general interest in infection control) were also significant for the proportion of measures considered ‘very effective’ in linear regression. In addition to these 2 factors, 1 other factor, namely the level of preparedness for a future equine influenza outbreak, was significant in linear regression analysis.

Lower perceptions of biosecurity effectiveness for interviewees residing in the special restricted area during the 2007 outbreak is not unexpected as lifting of quarantine orders and unrestricted movement within this zone occurred during the outbreak to allow for virus burn-out and to free resources as the relevant areas were considered to have high prevalence and horse density and virus spread in this area was considered to occur regardless of control efforts (NSW DPI, 2007b; EI EISG, 2008).

Higher perceptions of biosecurity effectiveness are associated with greater levels of preparedness for a future equine influenza outbreak (linear model only) and greater general interest in infection control. It is likely that these perceptions are interrelated and, generally, these findings may suggest that these individuals have a greater level of perceived fear or greater threat perception associated with a future disease outbreak (Maddux and Rogers, 1983). The relationships between perceptions and how they influence behaviour are complex, but social science theories such as protection motivation theory (Maddux and Rogers, 1983) suggest that fear indirectly influences attitude by influencing the appraisal of threat severity. In this study 1 measure of threat severity was the impact of a future equine influenza outbreak or another equine disease outbreak on the individual; i.e. greater perceived impact would indicate greater perceived negative consequences and translate to higher perceived severity of the threat. Owners and managers who feel the recommended biosecurity measures are effective in protecting their horses are also likely to perform these measures in any future outbreak, and consequently this may result in a greater sense of self-efficacy and control. Our study captured this heightened sense of perceived self-efficacy and control through the measurement of perceived preparedness for a future outbreak.

Being interested in infection control in general and being prepared for another (future) equine influenza outbreak may be related to previous experience of equine influenza, and this in turn may increase fear of future disease impacts. Having experienced the 2007 equine influenza outbreak, an epidemic of a novel highly infectious disease, horse owners/managers may be more motivated to learn about other equine infectious diseases and how they can be controlled. Infectious disease knowledge has been found to be important for motivating people to comply with recommended protective behaviours (Eastwood et al., 2009; Bish and Michie, 2010) as knowledge leads to a greater understanding of the mechanisms of disease spread and therefore greater confidence in the effectiveness of recommended protective measures. Conversely, French dairy farmers with insufficient knowledge of disease mitigation strategies have previously been shown to have higher risk of disease in their animals (Faye, 1992). Therefore better engagement strategies should be developed for those owners and managers currently least interested in infection control.

4.3. Strengths and limitations

In this study 2 approaches were used to investigate factors associated with the perception of high biosecurity effectiveness, namely binomial logistic regression and linear regression. Despite emphasising different aspects of the data through different outcome measures, results of both methods were similar, yet the linear regression model is considered more powerful as less information is lost from the original data. Furthermore the logistic regression model is limited as there are relatively few ‘low effectiveness’ outcomes in the dataset, which may have lead to over- or under-estimation of variances and hence may have affected parameter estimates and test statistics (Hosmer and Lemeshow, 2000). Selection bias due to random selection from the NSW DPI laboratory databases for the concurrently conducted case-control study (Firestone et al., 2011) reduces the external validity and hence generalisability of the results, yet no other sampling frame for Australian horse owners was available due to a lack of legal requirements for registration of horses in Australia.

A common limitation of epidemiological studies conducted using questionnaires is the subjective nature of the outcome and explanatory variables. To avoid resulting misclassification bias, only closed categorical responses were allowed to maximise the accuracy of the responses. Additionally, many questions included the option for interviewees to respond that they did not know the answer or that a measure was not applicable. These options were provided to address potential misclassification bias, where respondents may select an answer at random, as such observations were treated as missing in the analysis. Another potential source of bias, confounding, was addressed in this study by assessing potential confounding effects of age and gender of participants through forcing these two variables into the final models, yet they were not significant and no confounding effects were found in this study. Generally it can be expected that effectiveness perceptions are influenced by what measures were actually performed during the outbreak in 2007 and were remembered by interviewees. However, this relationship was not evaluated in these analyses. Face-to-face on-farm interviews were conducted in this study to increase cooperation, rapport, consistency and reliability of the responses as well as completeness of the data. To improve recall of the time of the 2007 outbreak, open discussions led up to the questioning to stimulate memory; however some degree of recall bias is possible and the horse involvement of respondents may have changed between the time of the outbreak and interview.

5. Conclusions

This study identified that private veterinarians were frequently used as infection control information sources during an exotic infectious disease outbreak. Further, it found that those who received infection control information from a veterinarian during the outbreak, those who did not experience equine influenza infection in their horses and those from small acreage homes with horses on site, were all more likely to perceive equine influenza biosecurity measures as effective. Additionally, greater preparedness for a future equine influenza outbreak and greater general interest in infection control information were associated with perceptions of greater biosecurity effectiveness, whilst residing in the highly affected special restricted area during the 2007 outbreak was negatively associated with these perceptions. These findings should be considered in the design of future infection control programs in order to sway effectiveness perceptions and to ultimately increase horse owners' and managers' biosecurity compliance.

Conflict of interest

The researchers disclose that the corresponding author (KS) owns a horse and has been employed in various equine industries, however we do not believe that this has inappropriately influenced this work.

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Table 1

Equine influenza biosecurity measures used to create outcome variables in a study of 200 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

Biosecurity measure	n [a]	Very effective (%)	Partially effective (%)	Not effective (%)
Not sharing horse gear	189	95	5	0
Controlling who has access to your horses	199	91	8	1
Reducing your own contact with other horses	200	88	11	1
Reducing your horses' contact with other horses	199	86	10	4
Ensuring that feed and bedding comes from a clean source	192	86	10	4
Reducing visits by horse professionals to the property	197	86	10	4
Complying with movement restrictions	200	85	9	6
Using soap when washing your hands	198	78	15	7
Washing your hands before contact with your horses	198	72	20	8
Changing your shoes on arrival at your property	198	69	22	9
Disinfecting horse floats before use	183	66	21	13
Ensuring that any new horses are isolated from your other horses	181	65	14	21
Changing into clean clothes on arrival at the property	196	63	28	9
Ensuring all visitors use a disinfectant footbath	193	63	23	14
Disinfecting vehicles entering your property	192	50	27	23
Showering on arrival at your property	190	44	36	20
Cleaning your horse gear before use	191	39	23	38

[a] Any 'not applicable' responses were treated as missing values.

Table 2

Explanatory variables analysed for associations with perceptions of effectiveness of recommended on-farm biosecurity measures amongst 200 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

Variable group	Variables
Respondent and premises descriptors	Age [a] ; Gender [b] ; Number of horses [c,d]; Involved in horse racing (thoroughbred or harness) [d]; Involved in equestrian events (dressage, showjumping, eventing, endurance) [d]; Involved in horse showing [d]; Involved in rodeo-style horse events (camp-drafting, cutting, barrel-racing) [d,] ; Horse breeders [d]; Horses kept for other owners [d]; Horses kept only for recreation [d]; Horses used for farm work [d]. Premises enterprise type [b,d]; Income derived from horses [a,d]; Regional cluster as per Cowled et al. (2009) [b].
Sources of infection control information during the outbreak	Internet ; General media (television, newspaper, radio); Other horse owners; Veterinarians; Other horse professionals (farriers, dentists, chiropractors, trainers, coaches) ; Australian Horse Industry Council (AHIC) ; State Department of Primary Industries (NSW DPI) ; Association/society (breed, sporting) ; Horse equipment or feed retailers.
Outbreak experience and biosecurity perceptions	Premises infected during the 2007 outbreak; Experience with equine influenza infection during the outbreak [b]; Outbreak control zone [b]; Perceived stringency of own biosecurity measures [a]; Perceived level of stringency compared to horse owners in the neighbourhood [a]; Perceived level of vulnerability to a future equine influenza outbreak; Perceived level of preparedness for a future equine influenza outbreak [a]. General interest in infection control information [a].

All variables are binary (1=Yes, 0=No) unless indicated otherwise. [a] Ordinal variable; [b] Categorical variable; [c] Continuous variable; [d] These variables relate to status at the start of the outbreak (25 August 2007).

Table 3

Contingency tables and univariable logistic regression results for horse involvement related explanatory variables associated with the perceptions of high effectiveness of biosecurity measures (*p*<0.20) in this study conducted with 200 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

	Biosecurity effectiveness						
Variables and categories	High	Low	b	SE(b)	Odds ratio	95% CI	*p*-value
Premises enterprise type							0.069
Small acreages/homes with horses	84	9	0	-	1.00	-	-
Commercial studs	15	3	-0.62	0.72	0.54	0.14, 2.62	-
Farms- cattle, sheep or cropping	30	7	-0.78	0.55	0.46	0.16, 1.39	-
Equestrian centres or riding schools	26	10	-1.28	0.51	0.28	0.10, 0.76	-
Agistment- horses kept for other owners	11	5	-1.45	0.64	0.24	0.07, 0.88	-
Horses kept only for recreation							0.076
Yes	65	8	0.74	0.43	0.55	0.23, 1.42	-
No	101	26	0	-	1.00	-	-
Involved in horse-racing							0.100
Yes	13	6	-0.93	0.53	0.40	0.14, 1.21	-
No	153	28	0	-	1.00	-	-

Table 4

Contingency tables and univariable logistic regression results for variables associated with high biosecurity effectiveness perception (p<0.20) amongst 200 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

	Biosecurity effectiveness						
Variables and categories	High	Low	b	SE(b)	Odds ratio	95% CI	*p*-value
Outbreak control zone							0.037
Special restricted area	47	16	0.00	-	1.00	-	-
Restricted area	119	18	0.81	0.38	2.25	1.05, 4.79	-
Premises infected with equine influenza							0.028
Yes	100	27	-0.93	0.45	0.39	0.15, 0.91	
No	66	7	0.00	-	1.00	-	-
Experience with equine influenza infection during the outbreak							0.012
Infected- believed spread via direct and indirect means only	43	6	-0.27	0.59	0.76	0.24, 2.51	-
Infected- believed spread via wind	57	21	-1.25	0.47	0.29	0.11, 0.70	-
Not infected	66	7	0.00	-	1.00	-	-
Perceived level of preparedness for a future outbreak							0.056
Highly prepared	55	5	1.51	0.65	4.53	1.29, 17.13	
Prepared	93	19	0.70	0.51	2.02	0.70, 5.40	
Unprepared	17	7	0.00	-	1.00	-	-
General interest in infection control information							0.090
Very interested	96	13	1.05	0.53	2.87	0.97, 8.08	
Interested	52	14	0.37	0.54	1.44	0.48, 4.08	
Not interested	18	7	0.00	-	1.00	-	-
Used a veterinarian as infection control information source during the 2007 outbreak							0.002
Yes	133	18	1.28	0.39	3.58	1.65, 7.80	-
No	33	16	0.00	-	1.00	-	-
Used a retailer as infection control information source during the 2007 outbreak							0.036
Yes	32	2	1.34	0.76	3.82	1.08, 24.33	-
No	134	32	0.00	-	1.00	-	-
Used a non-veterinarian horse professional as infection control information source in 2007							0.167
Yes	48	14	-0.54	0.39	0.58	0.27, 1.26	-
No	118	20	0.00	-	1.00	-	-

Table 5

Final logistic regression model for the perception of high effectiveness biosecurity measures amongst 200 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

Variables and categories	b	SE(b)	Adjusted odds ratio	95% CI	*p*-value [a]
Constant	0.97	0.92	-	-	-
Used a veterinarian as an infection control information source during the 2007 outbreak					0.001
Yes	1.58	0.49	4.83	1.89, 13.05	-
No	0.00	-	1.00	-	-
Premise enterprise type					0.002
Small acreages/homes with horses	0.00	-	1.00	-	-
Agistment- horses kept for other owners	-1.56	0.77	0.21	0.05, 1.00	-
Commercial studs	-2.07	0.87	0.13	0.02, 0.76	-
Equestrian centres or riding schools	-2.00	0.62	0.14	0.04, 0.44	-
Farms- cattle, sheep or cropping	-2.26	0.80	0.10	0.02, 0.48	-
Experience with equine influenza infection during the 2007 outbreak					0.008
Infected- believed spread via direct or indirect contact	-0.71	0.76	0.49	0.11, 2.20	-
Infected- believed spread via wind	-1.92	0.73	0.15	0.03, 0.56	-
Not infected	0.00	-	1.00	-	-
General interest in infection control information					0.020
Very interested	1.83	0.69	6.23	1.62, 25.02	
Interested	0.90	0.64	2.47	0.69, 8.67	
Not interested	0.00	-	1.00	-	-
Outbreak control zone					0.032
Special restricted area	0.00	-	1.00	-	-
Restricted area	1.12	0.53	3.06	1.10, 9.07	

Log likelihood= 43.4; d.f.=10; $p<0.001$; Goodness-of-fit deviance χ^2-test statistic $p=0.56$; [a] *p*-values based on likelihood ratio χ^2-test of significance.

Table 6

Univariable linear regression results for explanatory variables associated with the proportion of the 17 biosecurity measures perceived to be 'very effective' ($p<0.20$) by 200 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

Variables and categories	b	SE(b)	95% CI for b	*p*-value
Outbreak control zone				
Intercept	0.75	0.02	0.71, 0.79	<0.001
Special restricted area	-0.09	0.04	-0.16, -0.01	0.030
Restricted area	0.00	.	.	.
Premises infected with equine influenza				
Intercept	0.77	0.03	0.72, 0.83	<0.001
Yes	-0.08	0.04	-0.16, -0.01	0.033
No	0.00	.	.	.
Regional cluster per Cowled et al. (2009)				
Intercept	0.77	0.05	0.68, 0.86	<0.001
Lower Hunter	-0.03	0.07	-0.17, 0.12	0.720
Upper Hunter	-0.07	0.06	-0.19, 0.05	0.236
Windsor	-0.12	0.06	-0.23, 0.00	0.045
Narrabri	0.00	0.06	-0.11, 0.12	0.985
SW Sydney	0.00	.	.	.
Perceived level of preparedness for a future outbreak				
Intercept	0.55	0.05	0.46, 0.65	<0.001
Highly prepared	0.26	0.06	0.15, 0.37	<0.001
Prepared	0.18	0.05	0.07, 0.28	0.001
Unprepared	0.00	.	.	.
Used a veterinarian as infection control information source during the 2007 outbreak				
Intercept	0.61	0.04	0.54, 0.68	<0.001
Yes	0.15	0.04	0.07, -0.23	0.001
No	0.00	.	.	.
General interest in infection control information				
Intercept	0.64	0.05	0.54, 0.74	<0.001
Very interested	0.14	0.06	0.02, 0.25	0.018
Interested	0.04	0.06	-0.08, 0.16	0.485
Not interested	0.00	.	.	.
Perceived level of vulnerability to a future outbreak				
Intercept	0.76	0.03	0.69, 0.82	<0.001
Vulnerable	-0.05	0.04	-0.13, 0.03	0.185
Not vulnerable	0.00	.	.	.

Perceived stringency of own biosecurity measures applied during the 2007 outbreak				
Intercept	0.64	0.07	0.50, 0.79	<0.001
More stringent than normal practices	0.10	0.08	-0.05, 0.26	0.180
Normal practices	0.04	0.08	-0.13, 0.20	0.662
Less stringent than normal practices	0.00	.	.	.
Involved in horse-racing				
Intercept	0.63	0.06	0.51, 0.74	<0.001
No	0.11	0.06	-0.01, 0.23	0.085
Yes	0.00	.	.	.

Table 7

Final linear regression model for perceptions of biosecurity effectiveness of 196 horse owners and managers affected by the 2007 equine influenza outbreak in Australia.

Parameters	b	SE(b)	95% CI for b	*p*-value
Intercept	0.54	0.06	0.41, 0.66	.
Perceived level of preparedness for a future EI outbreak				<0.001
Highly prepared	0.23	0.06	0.12, 0.35	
Prepared	0.17	0.05	0.06, 0.27	
Unprepared	0.00	.	.	
Outbreak control zone				0.003
Special restricted area	-0.11	0.04	-0.18, -0.04	
Restricted area	0.00	.	.	
General interest in infection control information				0.039
Very interested	0.12	0.06	0.00, 0.23	
Interested	0.03	0.06	-0.08, 0.15	
Not interested	0.00	.	.	