Horse owners' biosecurity practices following the first equine influenza outbreak in Australia

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Abstract

A cross-sectional study was conducted involving 759 Australian horse owners to determine their biosecurity practices and perceptions one year after the 2007 equine influenza outbreak and to investigate the factors influencing these perceptions and practices. A web link to an online questionnaire was sent to 1224 horse owners as a follow-up to a previous study to obtain information about biosecurity perceptions and practices, impacts of the 2007 EI outbreak, demographic information and information about horse industry involvement. Ordinal logistic regression analyses were conducted to determine factors associated with poor biosecurity practices. Biosecurity compliance (low, medium, high), as determined by horse owners' responses to a 16-item question on the frequency of various biosecurity measures, was used as the outcome variable in ordinal logistic regression analyses. Variables with a univariable p-value ≤0.2 were eligible for inclusion in multivariable models built using a manual stepwise approach. Variables with a p-value <0.05 in multivariable models were retained in the final model. Two potential confounders - age and gender of participants- were included in the final model irrespective of their p-values.

Thirty percent of the respondents had low biosecurity compliance and were performing biosecurity practices 'not very often' or 'never'. Younger people, people with two or more children, those who were not involved with horses commercially and those who had no long-term business impacts resulting from the 2007 EI outbreak were more likely to have lower biosecurity compliance. People who were not fearful of a future outbreak of equine influenza in Australia and those who thought their current hygiene and access control practices were not very effective in protecting their horses also had poor biosecurity practices.

In this observational study we identified factors associated with a group of horse owners with low levels of biosecurity compliance. As this cross-sectional study only assesses associations, the identified factors should be further investigated in order to be considered in the design of extension activities to increase horse owners' biosecurity compliance.

Keywords: Biosecurity; Equine; Owner perceptions; Ordinal logistic regression.

1. Introduction:

In late August 2007, Australia experienced its first ever outbreak of equine influenza (EI), 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). The virus spread through major parts of the state of NSW and into south eastern Queensland during the course of the outbreak. The outbreak lasted for four months from the initial confirmation of the virus in the general population on 24th August 2007 until the last case was detected in Queensland on 25th 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 the issuing of biosecurity guidelines (NSW DPI, 2007; DEEDI, 2011a). Biosecurity guidelines included personal hygiene as well as equipment hygiene and access control measures.

The 2007 EI outbreak raised horse owners' awareness of the importance of biosecurity measures to prevent disease outbreaks (DAFF, 2011). In a study conducted during the period of the EI outbreak, the majority of the respondents reported practising at least some access control and personal hygiene measures (Taylor et al., 2008; Taylor and Agho, 2009). Most of the respondents in that study believed that these measures were effective in reducing the spread of EI. Another survey conducted with 1870 Australian horse owners in 2008 revealed that 48% of respondents were in favour of, but 32% against, the ongoing implementation of biosecurity and quarantine measures in day-to-day horse activities (AHIC, 2008). We conducted this study to investigate the biosecurity perceptions and practices of horse owners one year after the 2007 EI outbreak and to characterise owners with low biosecurity compliance.

Despite the importance of equestrian pursuits in Australia (Gordon, 2001), the presence of infectious endemic diseases such as strangles or equine herpesvirus, and the occurrence of emerging infectious diseases such as EI and Hendra (DAFF, 2011), to date research on biosecurity practices of Australian horse owners has been limited to the aforementioned studies. In contrast to Australia, efforts have been undertaken in the United States to describe biosecurity practices on equine operations and to monitor trends and compare changes between studies conducted in 1998 and 2005 as part of the National Animal Health Monitoring System (NAHMS) (USDA, 2006). The NAHMS studies examined biosecurity relating to potential contamination of feed and water, insect and animal disease vector control and isolation when animals arrive or return to the premise (USDA, 2006). Interestingly, the

2005 study found an increase in premises isolating equids returning to the operation after direct contact with outside equids compared to 1998, if the animal is diseased or believed to have been exposed to disease (USDA, 2006). Similarly, a New Zealand study examined biosecurity practices on thoroughbred stud farms and found general awareness of the need for biosecurity, but little on-farm implementation in the absence of disease (Rogers, 2010). Another study conducted with 64 equine boarding facilities in Colorado scored biosecurity measures related to the general facility, written health protocols, movement and housing of equids, infection control and isolation practices, and visitor and employee biosecurity practices. Most facilities in this study received the highest scores for movement and housing measures (Kirby et al., 2010). A better understanding of horse owners' biosecurity perceptions will greatly assist communication initiatives related to infectious disease control. Knowledge of factors influencing biosecurity compliance will facilitate the design of infection control programmes for future exotic disease incursions and for endemic diseases.

2. Methods:

2.1. Questionnaire design and sampling

An online questionnaire (available upon request) was designed to obtain information regarding the demographics of participants, the nature of their current involvement with horses, their attitudes towards biosecurity measures, the frequency of biosecurity practices, the impact of the 2007 EI outbreak on them and their attitudes towards a potential future outbreak. The questionnaire took approximately 20-25 minutes to complete and contained a total of 38 closed questions expressed in plain language to minimize confusion and to maximize the accuracy of the responses (Thrusfield, 2007; Dohoo, 2009). In addition, space was provided for making descriptive comments. The questionnaire also contained questions relating to general health of the respondent, drought status of the area of residence, impacts of the global financial crisis and perceptions of Hendra virus; however these data are not presented in this paper. The questionnaire was reviewed by subject experts including representatives of the NSW Department of Primary Industries (DPI), the Australian Horse Industry Council (AHIC) and the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) and modified after piloting with three horse owners from different equestrian disciplines. The University of Western Sydney ethics committee gave ethics approval for this study (Protocol No.H6612).

This study was designed as a follow-up study with participants of a 2007 online study investigating psychological distress among horse owners due to EI (Taylor et al., 2008) and biosecurity perceptions and practices (Taylor and Agho, 2009). It was not possible to identify the target population of Australian horse owners accurately and the original 2007 study therefore relied on an email alerting service through AHIC using the national Horse Emergency Contact Database (HECD); an internet-based database comprising contact details for both individuals and horse industry organisations (Oliver, 2007). The AHIC represents all major Australian horse sporting and breeding associations, including racing and equestrian sports, as well as recreational riders (AHIC, 2011a). Surveys conducted using the AHIC HECD database demonstrated a broad coverage of all major Australian horse sectors among their participants (AHIC, 2007, 2008). This database has also previously been used as a network to contact and inform horse owners during emergencies such as bushfires, the EI incursion and other disease outbreaks (Taylor et al., 2008).

In the original 2007 online study, 1224 participants expressed their interest in participating in future research by supplying their email addresses. The initial invitation to participate in the current study was sent out to these 1224 participants on 2nd December 2008. The survey remained open until 7th January 2009. Reminder emails were sent on 9thDecember 2008, 22nd December 2008 and 3rd January 2009.

2.2. *Statistical data analysis*

All statistical analysis were conducted using SAS statistical software (release 9.2 © 2002-2008, SAS Institute Inc., Cary, NC, USA) unless otherwise stated.

2.2.1. *Outcome variable*

A biosecurity compliance index (low, medium, high) was created based on horse owners' responses to a 16-item question on the frequency of biosecurity measures relating to personal and equipment hygiene as well as to access control measures on the property (Table 1[1]). The 16 items were based on guidelines issued by the NSW Department of Primary Industries and the Australian Government Department of Agriculture, Fisheries and Forestry in 2007 (DAFF, 2007; NSW DPI, 2007). Responses for the frequency for each of these 16 items were scored on a scale of 1 to 5, with 1 meaning 'every time' and 5 meaning 'never'. Respondents were categorised into three groups based on their median response to these 16 items: high (≤2), medium (>2 and ≤3) and low (>3) biosecurity compliance. This biosecurity compliance index was used as an outcome variable in univariable and multivariable ordinal logistic regression to identify factors associated with low biosecurity compliance.

2.2.2. *Explanatory variables*

A total of 38 explanatory variables were considered in this study. Explanatory variables were grouped according to the type of factor that they described into demographic factors, horse involvement related factors, perception-based explanatory variables and explanatory variables related to non-financial long-term impacts due to the 2007 EI outbreak (Tables 3-7). Two variables, namely 'age' and 'gender' of respondents, were forced into all multivariable models as they were expected to be confounders *a priori*. Two explanatory variables, the 'level of formal education' and the 'number of children', were derived by linking the survey results via computer id to the original survey (Taylor et al., 2008). All explanatory variables were binary or ordinal apart from two which were continuous, namely 'financial loss due to EI' and 'number of horses owned'.

2.2.3. *Descriptive analyses*

The distributions of categorical and continuous explanatory variables were assessed with frequency distributions and histograms, respectively. Further, we examined contingency tables of the categorical explanatory variables and box-and-whisker plots of the continuous explanatory variables for the categories of the biosecurity compliance index outcome (low, medium and high).

[1] All tables are located at the end of this document.

2.2.4. Univariable analyses

Univariable ordinal logistic regression analyses were conducted facilitated by UniLogistic SAS macro (Dhand, 2010) to investigate the unconditional association of explanatory variables with the outcome variable using cumulative logit models (Hosmer and Lemeshow, 2000). Based on these unconditional associations, all explanatory variables with univariable likelihood-ratio chi-square p-value of ≥0.20 were excluded from multivariable analyses. In addition, variables with more than 10% of missing values were initially excluded from multivariable analyses, but later retested by including them in the final model. Variables with univariable likelihood ratio chi-square p-value of <0.20 were tested for collinearity in pairs by calculating Spearman's rank correlation coefficient (ρ) for pairs of ordinal variables and by performing Pearson chi-square test for other pairs of variables. Highly correlated ($\rho>|0.70|$ and Pearson chi-square $p<0.05$) explanatory variables were examined and only the one of a pair of highly correlated variables which was more strongly associated with the outcome was retained for further analyses. Continuous variables were examined for the assumption of linearity by categorising the variables by quartiles and plotting mid-points of the categories against their respective regression coefficients (Hosmer and Lemeshow, 2000). The categorised variable was used in further analyses, if the assumption of linearity was not valid.

2.2.5. Multivariable analyses

Multivariable ordinal logistic regression models were constructed using in-house developed MultiLogistic SAS macro (http://sydney.edu.au/vetsci/biostat/macros/) with a manual forward stepwise approach to evaluate the association of explanatory variables with the outcome after adjusting for each other. The variables, which achieved statistical significance (p-value <0.05) in multivariable models, were retained in the final model. The gender and age group of the participants were considered confounders *a priori* and therefore forced into the final model irrespective of their p-values. Proportional odds assumption of the cumulative logit model was tested by the score test (Clark, 2005). Finally, variables with a univariable p-value >0.20 were retested by adding them one at a time to the final model as they might have become significant after adjusting for the variables in the model. Biologically important two-way interactions of the explanatory variables in the final model were examined and retained if significant ($p<0.05$).

2.2.6. Content analysis of comments regarding biosecurity practices

After providing ratings for each of the 16 individual biosecurity practices, respondents were offered the opportunity to provide freehand comments relating to these practices. These data were analysed using content analysis. Each respondent's comments were read three times to ensure familiarity with the data and then coded. The coding procedure used was 'interpretive' and therefore driven by the data itself and not by pre-determined categories (Franzosi, 2004). Comments were grouped together based on broad thematic categories. Key issues were noted if they were repeated by different responders and their frequency distributions were assessed. This analysis was performed using Microsoft Access (Microsoft Office Access 2007).

3. Results:

A total of 822 respondents participated in the online survey (response rate of 67.2%); however, 47 did not own or partly own a horse and were therefore excluded from the study. A further 16 respondents had missing values for the questions forming the outcome variable and were consequently excluded. Of the remaining 759 respondents, 30% had low, 20% medium and 50% had high biosecurity compliance. These respondents were from all Australian States and Territories except the Northern Territory and the majority (88%) were female (Table 2). More than two thirds of the respondents (72%) did not experience equine influenza infection in their horses during the 2007 outbreak in Australia; however over half of the respondents (54%) were residing in an outbreak control zone at the time. The age distribution of the respondents is shown in Table 3.

For horse enterprise, respondents were able to specify multiple sectors. The majority of respondents indicated recreational involvement (n=552, 71%), however, of those only 146 (19%) were exclusively involved in that sector. Involvement in equestrian/ sporting competitions was specified by 57% (n=443); 14% (n=112) were involved in racing industries whilst 36% (n=278) were involved in horse breeding. A further 15% (n=115) indicated that they were involved with agistment of horses (the grazing or stabling of horses belonging to other owners on their property for remuneration), 13% (n=102) were commercially involved with horses through riding schools, retail or tourism and

8% (63) were horse health professionals, practising as veterinarian, farrier, equine dentist or chiropractor.

3.1 Univariable ordinal logistic regression analyses for biosecurity compliance index

Contingency tables of 27 variables significant in univariable models (P < 0.20) are shown in Tables 3-6 for demographic variables, horse involvement related variables, perception-based variables and variables related to non-financial long-term impacts resulting from the EI outbreak, respectively. Table 7 shows summary statistics and univariable p-values for the two continuous variables.

3.2 Multivariable ordinal logistic regression analyses for biosecurity compliance index

The assumption of linearity was met for the continuous variable ‘Number of horses owned’ but not for the variable ‘Financial loss due to the 2007 EI outbreak’, which was subsequently categorised and considered as categorical variable in further analyses. Of the 38 variables considered for analyses, eleven had univariable likelihood-ratio chi-square p-values of ≥0.2 and were therefore excluded from the multivariable model (Tables 3-6). Of the remaining 27 variables, two pairs of variables: ‘Financial loss due to the 2007 EI outbreak’ and ‘Financial loss due to the 2007 EI outbreak as % of annual household income’; and ‘Long-term financial impacts due to EI in the 2007 EI outbreak’ and ‘Long-term business impacts due to the 2007 EI outbreak’, displayed high collinearity resulting in exclusion of the former variable in each pair. A further three variables were excluded from multivariable analyses due to having more than 10% of missing values. The excluded variables were: ‘Ease of performing hygiene practices’, ‘Financial loss due to 2007 EI outbreak as % of annual household income’ and ‘Perceived long-term horse health effects due to EI infection’. Next, the remaining 22 explanatory variables were tested in multivariable ordinal logistic regression analyses using a manual forward stepwise approach. The variables previously excluded based on more than 10% missing values were added one at a time to the final model for retesting, but none of them achieved statistical significance. ‘Financial loss due to the 2007 EI outbreak’ was excluded from initial multivariable analyses due to multicollinearity, but as the variable it was correlated with was not significant in the final model, the categorised variable was added to the final model, yet it did not achieve statistical significance.

The final model based on 652 observations included eight explanatory variables (Table 8). Of the eight variables in the final model, three were demographic characteristics and five represented psychographic characteristics (attributes relating to personality, attitudes and interest), with the later reflecting three major factors for low biosecurity compliance (financial impact of EI, threat appraisal and perceptions about effectiveness of biosecurity practices). Young people aged 16-25 reported the poorest level of biosecurity compliance. Although comparative odds of lower biosecurity compliance appeared to reduce almost consistently from age 25 onwards, the odds ratios only became statistically significant from age 35 onwards and were not significant for people older than 65 years. Analysis also revealed that parents of two or more children were more likely to be in the lower biosecurity group compared to people with no children. Owners experiencing greater long-term business impacts due to the EI outbreak and those commercially involved with horses were more likely to have higher biosecurity compliance (Table 8). A clear trend emerged regarding fearfulness of owners of a future EI outbreak as the less fearful owners were of a future EI outbreak the more likely they were to have low biosecurity compliance. The largest association with having low biosecurity compliance was observed for the perception regarding perceived effectiveness of current access control measures: Those who thought their current practices were either ‘not effective or probably not effective’ for protecting horses from infection were more than 4.3 times more likely to have lower compliance when compared with those owners who deemed their current access control practices as either ‘probably effective or definitively effective’. A large association with low biosecurity compliance was also observed in relation to the perceived effectiveness of current hygiene practices: Those judging their measures as being ‘probably or definitively not effective’ were more than 3.5 times more likely to have lower compliance when compared with those owners who perceived their hygiene practices as ‘definitively or probably’ effective.

Score test for the proportional odds assumption was non-significant ($p = 0.54$), indicating that the cumulative logit model was appropriate for these data (Scott, 1997).

3.2 Content analysis of comments regarding biosecurity practices

In total, 181 participants (23.8%) provided qualitative responses about their biosecurity practices from which three major issues emerged: necessity of biosecurity measures, effectiveness of access control measures and practices of horse professionals.

Some respondents stated that they would shift their behaviour and followed/ would follow practices only during an outbreak (38/181; 21%) and that some measures are unnecessary, ineffective or impractical (9/181; 5%). Specifically, many respondents complained that they were unable to control the access to their horses, as they were kept adjacent to public space or held together with other people’s horses (20/181; 11%) or that it was difficult to avoid contact with other horses or not to share water during trial rides and competitions (14/181; 8%). Others claimed that some measures were not necessary as their horses did not move off their property and were isolated from other horses (18/181; 10%). Yet, a proportion of owners declared that biosecurity measures were a standard procedure for them due to their professional involvement with horses, even before the EI outbreak (17/181; 9%). Of these 17 owners who claimed to have good biosecurity procedures, 11 were involved in equestrian sports, 7 kept horses belonging to other owners on their property for remuneration (agistment), six were involved in horse breeding, four worked as trained professionals in the horse health sector (veterinarian, dentist, farrier, chiropractor) and two had commercial interests as thoroughbred racing and equestrian trainers.

Some comments related to the biosecurity practices of visiting professionals as many of the biosecurity compliance questions were about this. Several respondents commented that they trusted their horse professionals (veterinarian/ farrier etc.) to take all necessary precautions (24/181; 13%); whilst others stated that their professionals did not follow necessary infection control measures (15/181; 8%).

4. Discussion

The 2007 Australian EI incursion and more regular annual outbreaks of zoonotic Hendra disease in recent years highlighted the need for good biosecurity practices in the Australian horse industry (Beale et al., 2008; DEEDI, 2011b). In the wake of these disease incursions and given the increasing efforts to promote biosecurity in the horse industry (PIRSA, 2009; DAFF, 2011), effective infection control programmes are clearly necessary. An understanding of horse owners' biosecurity perceptions and practices is vital in the establishment of such programs for future exotic disease incursions and for the control of endemic diseases, if they are to be effective.

We conducted this cross-sectional study to characterise horse owners with low biosecurity compliance using an online questionnaire. This approach was used as it was not possible to define the sampling frame of Australian horse owners accurately due to the lack of a national legislative requirement for horse registration and secondly, it allowed us to reach a large number of owners via well-utilised existing channels. However, it is acknowledged that the sample may not represent the entire horse owner population and there may be selection bias in that only those respondents to the initial 2007 study who indicated willingness to participate in a follow-up study formed the sampling frame for this study. Nonetheless, the study sample represents members of a large number of horse sectors, including racing, breeding, sporting/competition, commercial riding schools, and recreational owners. In addition, the sampling frame used in the initial 2007 study represents the main target population currently able to be contacted for extension activities.

Further sampling bias was considered possible as 88% of the respondents were female but this could actually reflect the structure of the Australian equestrian industry. Comparison data from the AHIC indicates that our study sample mostly corresponds to known gender and geographic distributions of Australian horse owners (AHIC, 2011b) (Table 2). Furthermore, the American equestrian industry is considered to be made up of about 80% female participants (AHC, 2005) and the Australian industry may be assumed comparable due to similarities in culture and equestrian activities pursued in both countries.

Another limitation of this study, common to epidemiological studies conducted using self-report questionnaires, was the subjective nature of the outcome and explanatory variables. This could potentially result in misclassification bias, but only closed categorical responses were allowed to maximize the accuracy of the responses. Moreover, many questions included the option for respondents to indicate 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 and were treated as missing data for the purpose of the current analyses.

Confounding bias is also present in most epidemiological studies. In this study we considered age and gender as potential confounders *a priori* based on a recent review (Bish and Michie, 2010) that found age and gender to be key determinants of preventative and avoidant behaviours and that they are also associated with perceptions about health-protective behaviours during pandemics. In support of these findings, an experimental study showed that interventions to promote hand-washing in public restrooms targeting different perceptions such as knowledge, disgust and social norms can affect men and woman differently (Judah, 2009). Considering these findings in conjunction with research indicating that male veterinarians exhibit less precaution awareness for zoonotic risk than female veterinarians (Wright, 2008) we assumed that age and gender of horse owners would be associated with biosecurity perceptions (explanatory variables) and confound biosecurity compliance (the protective behaviour related to equine health used as the outcome in this study). We therefore controlled for the confounding effects of age and gender of participants by including both variables in all multivariable models, irrespectively of their p value. Being an observational study, the results only describe associations rather than causation, however, the associations found are plausible and in accordance with what is suggested by human psychological research on health protective behaviours (Weinstein, 1993). Nevertheless, further research is needed to confirm these associations in randomised controlled trials or cohort studies. Additionally, the results were not validated in this study and may reflect what owners say they do rather than what they actually do. However a recent American study that compared online survey results to on-site collected validation data found that agreement between what is said and what is done was fair to substantial (Kirby et al., 2010). Despite the potential limitations discussed, the results of this study are strengthened by its large sample size and representativeness of owners from all states and territories of Australia, except the Northern Territory (Table 2) and a wide range of industry sectors. Another strong point of this study is the analysis of ordinal data. The proportional odds model used in analyses relates the probability of being at one category of the outcome to the probability of being in any lower category, assuming that the relationship is the same for each category (Dohoo, 2009). In comparison to analysis of a binary outcome, this approach is more informative and powerful, as information from the data would otherwise be lost.

In common with studies examining human health protective behaviours, younger people were found to have low compliance with recommended practices (Bish and Michie, 2010). This is often attributed to a sense of invulnerability in young people, resulting in higher levels of risk-taking behaviour. Older people were more likely to report that they would perform self-protective behaviours in the event of a future avian influenza outbreak or future influenza pandemic (Lau, 2007; Barr, 2008). A potential explanation may be that older people feel more susceptible to being affected by disease (Barr, 2008) and that this personal vulnerability may be projected to their horses, resulting in higher levels of biosecurity compliance.

Parents with two or more children were also found to be more likely to have poor biosecurity compliance. Our findings of poor compliance by parents with two or more children may be due to general workload and time constraints placed upon them through their parental duties.

Actual or feared financial impacts related to the 2007 EI outbreak appeared to provide significant motivation to comply with biosecurity guidelines as both commercial involvement with horses in general and more specifically long-term adverse business or professional impacts (such as loss of achievement, status, market position or competitiveness) were significant factors in the final model. Previous research has shown that owners who received their primary income through horse-related industry were more than twice as likely to experience psychological distress during the 2007 EI outbreak than those who did not receive their primary income through horses (Taylor et al., 2008).

Threat appraisal was a significant factor influencing biosecurity compliance in addition to financial impacts discussed above; as responders who were not very fearful about a future outbreak achieved a lower biosecurity compliance index than those who were fearful. This finding is consistent with previous protection motivation theory research (Maddux and Rogers, 1983), which suggests that fear indirectly influences attitude and behavioural change by influencing the appraisal of severity of a threat, i.e. the impact of infectious disease. Further, increasing severity consistently leads to greater intentions to behave in a health-protective manner (Rogers and Mewborn, 1976; Rogers, 1997) and fear appeals have been shown to motivate or persuade humans to protect animals as well (Shelton, 1981). Similarly, severity was an important predictive factor for influenza preparedness in a study among Australian businesses (Watkins, 2007).

The third major factor that characterised people with low biosecurity compliance (besides financial impact and threat appraisal) was their perception regarding biosecurity effectiveness. We found that owners who perceived their current hygiene and access control practices not to be effective, indeed, had lower levels of biosecurity. We suspect that these owners acknowledge their poor practices and do not feel motivated to perform biosecurity. This lack of motivation could be due to poor coping appraisal; the belief that biosecurity measures are not effective generally (low response efficacy), that they are not able to perform them adequately (low self-efficacy), or that the ‘costs’ in terms of time, inconvenience and money are too high (high response cost). These have all been identified as determinants of health protective behaviours, and are core elements of many health behaviour models (Weinstein, 1993; Bish and Michie, 2010).

We suggest that the factors identified in this study are strongly associated with poor biosecurity; low financial impact, low threat appraisal and perceptions of low effectiveness of biosecurity practices, should be the focus of education campaigns, so that resources can be used more effectively. Based on the results of this study, extension activities should specifically target young people as well as people not financially dependent on horses as their primary source of income. However, more research is needed to identify the sectors within the horse industry in which these groups are well represented and to identify effective strategies to reach them. In addition, future education campaigns should appeal to the threat infectious diseases pose to the horse industry and include information on disease impact and transmission as well as the effectiveness of control measures.

Horse owners who will shift and change their practices during an outbreak of infectious disease are important for disease control efforts as they will quickly support a response. Further research is needed to characterise this group of horse owners, so that outbreak extension can be targeted at these ‘quick-wins’ in order to use resources as efficiently as possible.

Encouragingly, some participants indicated that biosecurity measures were practised, even before the EI incursion, because they were perceived as standard professional practices. The reasons for this perception may be associated with their horse involvement: Involvement in equestrian sports and holding other owners’ horses in a stable or on pasture for remuneration (agistment) may indicate greater opportunity for infectious disease transmission and hence greater levels of disease exposure for these groups. Furthermore horse breeders may also be more aware of, or more fearful about, exposure to endemic infectious diseases.

Specific comments relating to the ineffectiveness or excessiveness of, or the impractical nature of biosecurity measures were made by owners concerning horses on properties where horses of multiple owners are kept (agistment centres), and at competitions. Properties where horses of multiple owners are kept together may be subjected to many horse movements and turn-over of horses, and are likely to experience high thoroughfare of people. These characteristics make them important for control of infectious disease spread, so it is disconcerting that biosecurity implementation at properties keeping horses of multiple owners may be suboptimal.

The opinions of horse owners on the practices of horse professionals were divided, suggesting that veterinarians, farriers and other professionals display varied levels of biosecurity. Insufficient use of infection reducing practices has been previously identified for American veterinary hospitals (Wright, 2008). Establishment of written infection control policies has been recommended by many American researchers (England, 2002; Morley, 2002; Wright, 2008). In recent years, biosecurity policies have been recommended for equine veterinary hospitals in the state of Queensland after the latest incidences of Hendra virus infection among veterinarians (DEEDI, 2011b). However, further work is needed to elucidate whether differences in biosecurity practices exist among veterinarians, farriers, equine dentists and chiropractors in Australia.

5. Conclusions

Demographic groups associated with low biosecurity compliance in this study were younger people and people with two or more children. Poor compliance was also associated with people who were not involved with horses commercially and those who had no long-term business impacts resulting from the 2007 EI outbreak. Perceptions associated with poor biosecurity identified in this study were not being very fearful of a future outbreak of equine influenza and beliefs that current hygiene and access control practices are not very effective in protecting horses from disease. Our results indicate that voluntary biosecurity compliance is associated with both demographic and attitudinal factors and consequently we recommend that both should be considered in future research identifying priorities for extension activities.

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Table 1: The 16 biosecurity measures used to create the biosecurity compliance index for 759 Australian horse owners who responded to an online survey in 2008.

How often do you do the following:	
1	Disinfect floats before using for your horse/s if other horses have used it.
2	Ensure that on arrival any new horses at your property (or main horse contact site) are isolated from other horses for at least two weeks.
3	Maintain a high level of cleanliness of all horse gear (e.g. clean tack, rugs, feed/ water containers, and equipment).
4	Avoid sharing your horse gear with others on your property (main horse contact site).
5	Avoid sharing gear, feed and water bins when at events/ locations with other horses.
6	Ensure that your horse gear is clean and disinfected before using on your horse/s if it has been used by others.
7	Check your horse/s daily for symptoms of equine influenza and other infectious diseases.
8	Change your clothes before having contact with your horses, if you have been in contact with other horses.
9	Wash your hands before having contact with your horse/s.
10	Wash your hands before having contact with other people's horses.
11	Ensure you know about the recent horse-related contact of visitors to your property (or main horse contact site).
12	Keep a record of visitors who have contact with horse/s.
13	Ask visitors to avoid unnecessary contact with your horse/s and avoid access to stable areas and paddocks.
14	Ensure that visiting professionals (vets, farriers, dentists etc.) use clean equipment and have clean clothing when working on your horse/s.
15	Request visiting professionals to disinfect their gear and themselves before working on your horse/s.
16	Avoid unnecessary contact with other people's horses.

Respondents rated the frequency of performing each measure on a scale from 1 “every time” to 5 “never”. Subsequently the median value for each respondent was calculated and indexed into “high” (≤2) “medium” (>2 and ≤3) and “low” (>3), biosecurity compliance. An open comment area was also included in this section of the questionnaire.

Table 2: Description of 759 Australian horse owner respondents to an online survey of equine influenza biosecurity perceptions and practices in 2008.

Variable	N	Level	Frequency	Proportion [a]
Gender	759	Female	667	0.88 (0.83)
		Male	92	0.12 (0.17)
State	759	New South Wales	372	0.49 (0.32)
		Queensland	158	0.21 (0.19)
		Victoria	142	0.19 (0.25)
		South Australia	48	0.06 (0.06)
		Western Australia	11	0.01 (0.13)
		Australian Capital Territory	16	0.02 (0.02)
		Tasmania	12	0.02 (0.02)
		Northern Territory	0	0 (0.8)

[a] Proportion in parenthesis is comparison data for Australian horse owners from AHIC (2011b)(AHIC, 2010).

Table 3: Descriptive results for demographic explanatory variables significantly associated (P<0.2) [a] with low biosecurity compliance in the biosecurity practices study conducted with 759 horse owners in 2008 in Australia.

	Biosecurity compliance			
Variables and categories	High Freq (Row%)	Medium Freq (Row%)	Low Freq (Row%)	Total
Age group				
< 25 years	17 (30%)	15 (27%)	24 (43%)	56
25-34 years	42 (39%)	24 (23%)	41 (38%)	107
35-44 years	117 (49%)	52 (22%)	68 (29%)	237
45-54 years	125 (50%)	53 (21%)	72 (29%)	250
55-64 years	56 (62%)	14 (15%)	21 (23%)	91
65+ years	11 (61%)	2 (11%)	5 (28%)	18
Number of children [b]				
None	245 (52%)	91 (19%)	134 (29%)	470
One	54 (45%)	29 (25%)	35 (30%)	118
Two or more	58 (38%)	36 (24%)	57 (38%)	151

[a] Variables with P>0.2 not included in this table: Gender, Education level, State, Control zone during the 2007 equine influenza outbreak, Exposure to equine influenza; [b] Range of 'Two or more'= 2-4 children.

Table 4: Descriptive results for horse involvement related explanatory variables significantly associated (P<0.2) [a] with low biosecurity compliance in the biosecurity practices study conducted with 759 horse owners in 2008 in Australia.

	Biosecurity compliance			
Variables and categories	High Freq (Row%)	Medium Freq (Row%)	Low Freq (Row%)	Total
Horse-related income				
No	188 (46%)	79 (19%)	145 (35%)	412
Yes	180 (52%)	81 (23%)	85 (25%)	346
Long-term financial impacts due to the 2007 EI outbreak				
Extreme/ a lot	68 (61%)	19 (17%)	24 (22%)	115
Moderate/ a little	105 (52%)	54 (27%)	43 (21%)	213
Not at all	182 (43%)	84 (20%)	159 (37%)	437
Long-term business impacts due to the 2007 EI outbreak				
Extreme/ a lot	68 (66%)	19 (18%)	16 (16%)	103
Moderate/ a little	109 (55%)	40 (20%)	50 (25%)	199
Not at all	172 (40%)	93 (22%)	161 (38%)	426
Financial loss due to the 2007 EI outbreak as % of annual household income				
<5% loss	60 (41%)	32 (22%)	55 (37%)	147
5-30% loss	93 (51%)	45 (25%)	43 (24%)	181
31-70% loss	43 (68%)	10 (16%)	10 (16%)	63
61-100% loss	36 (72%)	7 (14%)	7 (14%)	50
Stud/ breeding involvement				
No	208 (43%)	105 (22%)	173 (36%)	486
Yes	160 (59%)	55 (20%)	57 (21%)	272
Commercial horse involvement [b]				
No	305 (46%)	140 (21%)	213 (32%)	658
Yes	63 (63%)	20 (20%)	17 (17%)	100
Horse health occupational involvement [c]				
No	333 (48%)	146 (21%)	218 (31%)	697
Yes	35 (57%)	14 (23%)	12 (20%)	61
Recreational involvement				
No	125 (55%)	36 (16%)	67 (29%)	228
Yes	259 (46%)	133 (24%)	168 (30%)	560
Equestrian/competition involvement				
No	118 (55%)	31 (14%)	66 (31%)	215
Yes	250 (46%)	129 (24%)	164 (30%)	543

EI= equine influenza; [a] Variables with P>0.2 not included in this table: Racing involvement, Keeping other owner's horses for remuneration (agistment); [b] Includes riding schools, retail, supply, tourism; [c] Includes veterinarians, farriers, dentists, chiropractors.

Table 5: Descriptive results for perception-based explanatory variables significantly associated (P<0.2) [a] with low biosecurity compliance in the biosecurity practices study conducted with 759 horse owners in 2008 in Australia.

		Biosecurity compliance			
Variables	Categories	High Freq (Row%)	Medium Freq (Row%)	Low Freq (Row%)	Total
Perceived effectiveness of current access control for protecting horses from infection					
	Definitely/ probably effective	196 (71%)	41 (15%)	40 (14%)	277
	Maybe effective	109 (48%)	70 (31%)	49 (21%)	228
	Probably/ definitively not effective	54 (24%)	44 (20%)	123 (56%)	221
Perceived effectiveness of current hygiene practices for protecting horses from infection					
	Definitely/ probably effective	170 (72%)	36 (15%)	31 (13%)	237
	Maybe effective	117 (49%)	71 (30%)	51 (21%)	239
	Probably/ definitively not effective	73 (29%)	48 (19%)	133 (52%)	254
Perceived fear of a future EI outbreak					
	Extremely/ very fearful	159 (61%)	43 (17%)	57 (22%)	259
	Moderately fearful	104 (44%)	60 (25%)	75 (31%)	239
	A little fearful	77 (41%)	39 (21%)	73 (39%)	189
	Not at all fearful	18 (35%)	12 (23%)	22 (42%)	52
EI knowledge					
	None/ limited	9 (37%)	5 (21%)	10 (42%)	24
	Moderate	116 (40%)	73 (25%)	104 (35%)	293
	High	176 (53%)	62 (19%)	95 (28%)	333
	Very high	65 (61%)	19 (18%)	22 (21%)	106
Perceived ability to cope in a future EI outbreak compared to 2007					
	Would cope better/ much better	149 (48%)	72 (24%)	85 (28%)	306
	Would cope the same	140 (45%)	65 (21%)	108 (34%)	313
	Would cope worse/ much worse	61 (58%)	15 (14%)	30 (28%)	106
Perception of seriousness of a future EI outbreak					
	Extremely/ very serious	320 (50%)	128 (20%)	192 (30%)	640
	Moderately serious	29 (34%)	24 (28%)	32 (38%)	85
	Not at all/ a little serious	7 (50%)	4 (29%)	3 (21%)	14
Perceived ease of performing hygiene measures					
	Very easy/ easy to do	43 (23%)	29 (16%)	113 (61%)	185
	Neither hard or easy to do	52 (18%)	69 (24%)	163 (58%)	284
	Hard/ very hard to do	36 (27%)	36 (27%)	62 (46%)	134
Perceived likelihood of a future EI outbreak					
	Extremely/ very likely	130 (55%)	42 (18%)	65 (27%)	237
	Moderately/ a little likely	216 (45%)	107 (23%)	153 (32%)	476
	Not at all likely	8 (53%)	3 (20%)	4 (27%)	15

Emotional preparedness for a future EI outbreak				
Extremely/ very prepared	91 (50%)	37 (20%)	56 (30%)	184
Moderately/ a little prepared	199 (45%)	104 (24%)	133 (31%)	436
Not at all prepared	60 (62%)	10 (10%)	27 (28%)	97

EI= equine influenza; [a] Variables with P>0.2 not included in this table: Perceived vulnerability to a future EI outbreak, Perceived rating of emotional/ social impact of a future EI outbreak compared to 2007 EI outbreak, Financial preparedness for a future outbreak, Perceived ability to deal with the financial impact of a future EI outbreak compared to 2007 EI outbreak.

Table 6: Descriptive results for explanatory variables representing non-financial long-term impacts of the 2007 equine influenza outbreak significantly associated (P<0.2) [a] with low biosecurity compliance in the biosecurity practices study conducted with 759 horse owners in 2008 in Australia.

		Biosecurity compliance			
		High	Medium	Low	
Variables	Categories	Freq (Row%)	Freq (Row%)	Freq (Row%)	Total
Long-term emotional impacts due to EI					
	Extreme/ a lot	54 (68%)	13 (16%)	13 (16%)	80
	Moderate/ a little	122 (54%)	41 (18%)	64 (28%)	227
	None	178 (42%)	99 (23%)	145 (35%)	422
Long-term social impacts due to EI					
	Extreme/ a lot	39 (64%)	9 (15%)	13 (21%)	61
	Moderate/ a little	115 (52%)	53 (24%)	52 (24%)	220
	None	198 (44%)	94 (21%)	160 (35%)	452
Long-term sporting impacts due to EI					
	Extreme/ a lot	80 (62%)	19 (15%)	30 (23%)	129
	Moderate/ a little	136 (49%)	59 (21%)	83 (30%)	278
	None	140 (43%)	77 (23%)	114 (34%)	331
Perceived long-term horse health effects due to EI infection					
	Did not have EI	124 (30%)	91 (22%)	198 (48%)	413
	Yes	13 (22%)	9 (16%)	36 (62%)	58
	No	55 (33%)	37 (22%)	75 (45%)	167

EI= equine influenza; [a] Variables with P>0.2 not included in this table: Perceived long-term horse performance effects due to EI infection.

Table 7: Descriptive information for continuous explanatory variables classified by the outcome variable biosecurity compliance in the biosecurity practices study conducted with 759 horse owners in 2008 in Australia.

Variable	Biosecurity compliance	Minimum	First quartile	Mean ± standard deviation	Median	Third quartile	Maximum	p^{a}
Financial loss due to the 2007 EI outbreak (A$ 1,000)								0.105
	High	0.0	2.0	39.8 ± 144.8	10.0	30.0	1500.0	
	Medium	0.0	0.5	17.9 ± 44.3	5.3	20.0	300.0	
	Low	0.0	0.0	23.5 ± 167.4	1.8	10.0	2000.0	
	Overall	0.0	0.5	30.7 ± 137.0	6.0	20.0	2000.0	
Number of horses owned								0.001
	High	1.0	2.0	9.1 ± 11.9	4.0	7.0	121.0	
	Medium	1.0	2.0	7.3 ± 9.3	4.0	9.0	78.0	
	Low	1.0	3.0	6.5 ± 9.5	5.0	11.0	100.0	
	Overall	1.0	2.0	7.9 ± 10.7	4.0	9.0	121.0	

EI=equine influenza. [a] Ordinal univariable likelihood ratio Chi-square *p*-value for low biosecurity compliance.

Table 8: Final multivariable ordinal logistic regression model (p<0.05) for low biosecurity compliance outcome variable based on data from 652 horse owners, who participated in an online survey on biosecurity perceptions and practices in 2008 in Australia

Parameters	b	SE(b)	Adjusted odds ratio	95% CI	*p*
Constant 1	-2.80	0.42	-	-	-
Constant 2	-1.62	0.41	-	-	-
Age					0.009
<25 years	0	-	1	-	-
25-34 years	-0.56	0.35	0.57	0.28, 1.14	-
35-44 years	-1.16	0.33	0.31	0.16, 0.61	-
45-54 years	-0.74	0.33	0.48	0.25, 0.90	-
55-64 years	-1.03	0.40	0.36	0.16, 0.78	-
65+ years	-1.13	0.66	0.32	0.09, 1.17	-
Gender [a]					0.156
Female	0	-	1	-	-
Male	0.37	0.26	1.45	0.87, 2.41	-
Perceived fear of a future EI outbreak					<0.001
Extremely/ very fearful	0	-	1	-	-
Moderately fearful	0.60	0.21	1.82	1.21, 2.72	-
A little fearful	0.82	0.22	2.27	1.46, 3.51	-
Not at all fearful	1.35	0.35	3.84	1.94, 7.61	-
Perceived effectiveness of current access control for protecting horses from infection					<0.001
Definitively/ probably effective	0	-	1	-	-
Maybe effective	0.53	0.22	1.69	1.10, 2.61	-
Probably/ definitively not effective	1.46	0.25	4.31	2.63, 7.08	-
Perceived effectiveness of current hygiene practices for protecting horses from infection					<0.001
Definitively/ probably effective	0	-	1	-	-
Maybe effective	0.62	0.23	1.86	1.18, 2.94	-
Probably/ definitively not effective	1.26	0.26	3.54	2.13, 5.87	-
Long-term business impacts due to 2007 EI outbreak					0.001

Extreme/ a lot	0	-	1	-	-
Moderate/ a little	0.36	0.29	1.43	0.82, 2.50	-
No impact	0.89	0.27	2.43	1.43, 4.13	-
Number of children [b]					0.004
None	0	-	1	-	-
One	0.18	0.24	1.20	0.76, 1.91	-
Two or more	0.74	0.22	2.09	1.36, 3.22	-
Commercial involvement [c]					0.039
No	0	-	1	-	-
Yes	-0.55	0.27	0.58	0.34, 0.97	-

EI= equine influenza; [a] Confounder forced into the model irrespective of its p-value; [b] Range of 'Two or more'= 2-4 children; [c] Includes riding schools, retail, tourism; Score test for proportional odds assumption $p = 0.542$; Deviance goodness of fit $p = 0.931$.