“Prevention is the biggest success”: barriers and enablers to personal biosecurity in the Thoroughbred breeding industry.

Kathryn Taylor [a,b,*], Susan Thomas [a,b], Diana Mendez [c], Catherine Chicken [d], Joan Carrick [e], Jane Heller [f], David Durrheim [a,b]

[a] University of Newcastle, Australia

[b] Hunter New England Local Health District, Australia

[c] James Cook University, Australia

[d] Scone Equine Centre, Australia e Equine Specialist Consulting, Australia

[f] Charles Sturt University, Australia

* Corresponding author

Abstract

Employees in the equine industry are at occupational risk of zoonoses such as Hendra virus and equine chlamydiosis through exposure to infected materials. This study aimed to gain a deeper understanding of the views and experiences of employees, and the key drivers of infection control and personal biosecurity (PB) practices in the Thoroughbred breeding industry. Methods: An exploratory qualitative study was conducted in 2018 in New South Wales, Australia using interviews (9) and small group discussions (7). The 29 participants included veterinarians, veterinary nurses, foaling staff, stud managers and laboratory personnel working in a range of equine medicine settings. Interviews and focus groups were recorded, transcribed and analysed manually by at least two members of the research team. An iterative approach was used to derive themes. Results: Five main themes emerged: (i) greater awareness of current and emerging infectious risks promotes use of Personal Protective Equipment (PPE); (ii) currently available PPE is not comfortable, practical or well-suited to equine reproductive work in Australia’s hot climate; (iii) creating supportive

environments for PB reduces risk of exposure to infectious materials; (iv) strong leadership is required to implement sustainable change in workplace culture and practices; and (v) policy and economic factors play an important role in adopting biosecurity (BS) and PB measures in the workplace. Personnel working in the Australian Thoroughbred breeding industry face unique zoonotic risks in a challenging physical environment. A qualitative approach provided rich insights into social and physical factors motivating BS and PB in this occupational group. There is an opportunity for collaboration between Public Health services and industry partners to develop and implement strategies most likely to be effective in ensuring consistent uptake of PB measures in the workplace.

Key words

Equine, Public health, Infection prevention and control, Biosecurity, Zoonoses, Occupational health

Introduction

The equine industry has faced many zoonotic disease risks, both established (cryptosporidiosis, Q fever) and emerging (Hendra virus, Methicillin Resistant Staphylococcus Aureus). In 2017, an epizootic of equine chlamydiosis highlighted parturition as a potential source of spillover of zoonotic pathogens, and the need for improved personal biosecurity (PB) practices among those involved in equine reproductive procedures.

People who work with animals encounter a range of occupational health and safety (OHS) risks, including injury, chemical exposure and zoonotic disease. In this context, biosecurity (BS) aims to prevent and reduce the risk of infection to other animals and ensuing consequences such as loss of herd health and economic fall-out (Merck Veterinary Manual 2020, Weese 2014), while PB refers to the measures implemented by veterinarians and other animal handlers to prevent or reduce the risk of exposure to an infection with a

55 zoonosis while working with animals (Australian Veterinary Association, 2017). PB strategies
56 are based on similar principles of infection prevention and control (IPC) used in human
57 healthcare settings such as hand hygiene, the use of personal protective equipment (PPE),
58 disinfection, vaccination and isolation (Australian Veterinary Association, 2017; National
59 Health and Medical Research Council, 2019). The scope and intent of BS, PB and ICP are
60 different but some of the strategies used overlap, hence it is not uncommon to find these
61 terms used interchangeably (Weese, 2014; Mendez, 2016).

62 The emergence of zoonotic diseases with potentially severe consequences such as Hendra
63 virus (HeV) has considerably raised the profile of zoonoses in Australian veterinary practice,
64 in particular for those working with horses (Kung et al., 2013; Mendez et al., 2014b; Balzer,
65 2015; Wiethoelter et al., 2017b). However, PB in the veterinary field is not universally
66 practised, despite these risks (Dowd et al., 2013a; Wiethoelter et al., 2017a; Willemsen et
67 al., 2019). This study seeks to explore the barriers and enablers of PB practices for people
68 working in the Thoroughbred horse breeding industry, including veterinarians, veterinary
69 nurses, horse owners and stud farm staff.

70 Australia is home to a major Thoroughbred breeding industry which is second only to the
71 United States of America (US) by horse population (Thoroughbred Breeders Association,
72 2019). *Chlamydia psittaci* infection of broodmares and newborn foals (resulting in fetal loss
73 and neonatal pneumonia/sepsis, respectively) has recently emerged as a potential zoonotic
74 risk to humans in three suspected outbreaks in Australia since 2014, resulting in nine
75 suspected, eight probable, and one confirmed cases of equine-associated psittacosis in
76 humans to date (Chan et al., 2017; Larter and Stow, 2017; Jenkins et al., 2018; Taylor et al.,
77 2018). In each of these clusters of equine-associated psittacosis, suboptimal PB practices
78 were utilised by personnel when examining reproductive membranes, foaling or flushing
79 mares, or examining and attending to septic neonates.

80 While PB attitudes and practices in the equine industry have been explored in the context of
81 Hendra virus (Mendez et al., 2014a; Mendez et al., 2014b; Wiethoelter et al., 2017a;

Wiethoelter et al., 2017b), less is known about the risks and practices of people working in equine reproduction. Research suggests adequate PB is less likely to be practised for obstetric compared to non-obstetric procedures, with one US study finding that >95% of veterinarians did not wear respiratory or eye protection when aiding a parturient animal or handling products of conception (Wright et al., 2008). In addition, a cross-sectional study conducted among Australian veterinarians, a third of which worked in a mixed or large animal practice, reported that almost half of the participants (143/288) did not use PPE or used an inadequate level of PPE (less than the minimal standard of PPE which included the use of overalls or a gown and gloves) when handling animals for conception or parturition procedures (Dowd et al., 2013).

The drivers of PB practices among animal health workers, as in human healthcare workers, are complex and varied. One of the main factors driving the implementation of PB and BS in the Thoroughbred industry across Australia and New Zealand is the likelihood of infection risk to horses and/or humans (Rogers & Cogger, 2010; Whiethoeler et al., 2017). Similarly, PB implemented by private equine veterinarians managing the emergence of HeV in Queensland depended on their risk assessments and perceptions, prior personal experience with HeV, training, work culture and constrains associated with working in private practice (Mendez et al., 2014a; Mendez et al., 2014b). Additionally private veterinarians in this region who worked in practices where PB and BS leadership was evident (reported presence of PB and BS policies, dedicated PB and BS staff, and OHS events documented) were more likely to use a mask when dealing with horses or birds (Mendez, 2016). A survey of Australian veterinarians found that level of education, perception of zoonotic risks from animals, conscious consideration of PPE use for every case and liability concerns were positively associated with adequate use of PPE (Dowd et al., 2013b). Conversely, low levels of perceived risk of zoonosis exposure, male gender and private (versus government) practice were identified as possible barriers in other studies (Wright et al., 2008; Anderson and Weese, 2016).

Despite what is known about drivers of PB in the veterinary/agricultural field, gaps remain in the literature. There remains a relative dearth of studies on PB in veterinary settings when compared to IPC practices in healthcare workers. Studies in the veterinary profession to date have largely utilised quantitative approaches, employing methodologies such as questionnaire/survey and video or direct observation of quantitated behaviours. However, qualitative approaches are well suited to exploring complex decision-making processes and may yield novel insights and strategies for effecting behaviour change (Christley and Perkins, 2010; Wiethoelter et al., 2017a). In addition, the majority of relevant literature has examined attitudes in veterinarians, rather than veterinary nurses or frontline stud farm workers. These occupational groups are likely to be at equivalent, or higher risk of contact with zoonotic pathogens.

In response to these knowledge gaps, a multidisciplinary one health research team was formed to further understand drivers of zoonotic risk among Thoroughbred breeding industry personnel. The aims of this study were: (i) to explore attitudes towards zoonotic illness risk; (ii) to better understand the key drivers of uptake of infection control and personal biosecurity practices; and (iii) to identify suitable targets for the development of zoonotic risk mitigation strategies among veterinarians, veterinary nurses and stud workers involved in equine reproduction. This paper focuses on aims (ii) and (iii), within the context of zoonotic risks that may face those in the industry, including HeV and equine-associated psittacosis.

Methods

Qualitative methods were used to gain a deeper understanding of factors influencing PB and potential strategies to minimise the risk of infection amongst those employed in the Thoroughbred breeding industry. Key informants were invited to participate in individual interviews or small group discussions to explore their experiences and views about the topic in their work settings. An advisory group comprising academics and human and veterinary

public health practitioners familiar with the industry and qualitative research methods provided study governance and oversight.

Setting and Participants

The study was conducted across two equine breeding regions in New South Wales, Australia. These areas were chosen due to the presence of significant Thoroughbred breeding communities, and recent local epizootics of equine chlamydiosis and associated clusters of respiratory disease in workers (Chan et al., 2017; Taylor et al., 2018).

We used purposive sampling to identify key informants working in the Thoroughbred breeding sector aged >18 years. Participants working closely with horses who had knowledge and experience in the use of PPE, PB and BS practices were invited from veterinary hospital settings, a university teaching clinic, community veterinary practice, and stud/breeder farms.

Relationships between the research team and community had been established at both sites through investigations of zoonotic disease outbreaks, including equine chlamydiosis, over the previous three years. Information sessions on the purpose, aims and methods of the study were delivered by research team members at workplace education sessions. Building on those relationships, invitations to participate in this study, along with information statements and consent forms were distributed by email and face to face methods to potential participants through key community veterinarians and local Thoroughbred breeding networks. Participants of a previous chlamydial serosurvey study were also invited by email. A snowballing technique was used where potential participants were encouraged to invite others they thought may have valuable insights.

Participation in the study was voluntary. Information provided by participants would not be used in any way that may identify individuals and so privacy and confidentiality was assured. No financial incentive for participation was offered to participants. Ethics approval was

obtained from the Hunter New England Human Research Ethics Committee (Reference No. 17/05/17/4.02

Interviews and small group discussions

Small group discussions were used for stud farm workers who were employed in similar roles, where deep discussion and reflection could occur in a setting where participants felt comfortable to interact with their peers. Individual interviews were used for managers and veterinarians who had knowledge of policy, guidelines and strategies and who may have introduced a power imbalance in small group discussion with other staff members. Individual interviews were also used to capture the views of individuals who may have missed the opportunity to participate in small group discussions. All interviews and small group discussions were conducted in locations and at times that were convenient to participants.

Data collection

The question guide was developed by the research team and reviewed by the governance group for validity. Simple open ended questions with prompts were piloted by the research team after which, the guide was separated into one for staff and another for those in managerial positions – the latter exploring organisational controls and PB management procedures in greater detail. Data were collected using a semi-structured interview format to allow participants to discuss areas of interest and concern. The line of enquiry was iterative and explored participants' background, experience of zoonotic disease, PB practices and barriers and enablers to use of PPE, while providing opportunity for additional comments on relevant topics.

Interviews and small discussion groups were conducted between July and September 2018 by KT and ST. KT is a public health physician with experience in control of infectious diseases, zoonotic disease transmission and equine psittacosis. ST is a registered nurse and a DrPH with a wide range of experience in both acute and community settings. Both are experienced in the use of PPE. ST is an experienced qualitative researcher and has

published a number of peer reviewed studies of public health interest. DM assisted with the study design, interpretation of transcripts, data analysis and development of the discussion. DM is a veterinarian with an MPH who completed a PhD on the topic of HeV management and associated infection control practices among veterinarians.

Data analysis

Interviews and small group discussions were digitally recorded with notes taken to assist with further inquiry during the interview and to note non-verbal cues from participants. Recordings were transcribed verbatim and analysed manually by ST, KT and DM using an iterative process of individual and group level review and interpretation of narrative data. A thematic analysis was used were codes were developed using key words, short phrases, quotations or concepts. These were then grouped by commonalities into categories relevant to the research aims. From the categories, the researchers developed themes that best described the essence of those categories. The process was flexible, with negotiation amongst researchers as the codes, categories and themes were refined, according to the flow of concepts and ideas.

Recruitment, interviewing and data analysis continued until a point of data saturation was reached, where no new ideas were discovered. Preliminary findings on the categories and themes were fed back to participants in August 2019, providing the opportunity for comment, clarification and validation. Supportive verbal comments on the results and their interpretation were provided by participants at the information session, participants were also invited to provide written feedback on the interim results but none was received.

Both KT and ST acknowledged an outsider bias, meaning they had little direct experience in the Thoroughbred industry. They used this bias to listen and learn from participants without preconceived ideas or assumptions. DM had an insider bias, which was used in data analysis to assist in the interpretation of textual data and context and in clarifying uncertainties.

Illustrative quotations of participants' responses are presented to explain and support the themes below.

Results

Twenty nine participants agreed to be interviewed. Interviews were conducted as follows: nine individual interviews, and seven small discussion groups (ranging from two to five participants in size). Participants worked across a range of settings and occupations, and were generally very experienced in the equine industry (Table 1). Small group discussion lasted 30-50 minutes and individual interviews between 20-45 minutes. Although the focus of this study was about PB, participants often talked about BS and PS measures interchangeably, this is reflected in the results presented below. Five main themes emerged: (i) greater awareness of current and emerging infectious risks promotes use of PPE; (ii) currently available PPE is not comfortable, practical or well-suited to equine reproductive work in Australia's hot climate; (iii) creating supportive environments for PB reduces risk of exposure to infectious materials; (iv) strong leadership is required to implement sustainable change in workplace culture and practices; and (v) policy and economic factors play an important role in adopting BS and PB measures in the workplace. These are discussed in greater detail below.

Demographics	N (%)
Gender	
M	9 (31)
F	20 (69)
Area of work	
Northern New South Wales	25 (86)
Southern New South Wales	4 (14)

Years of experience in the horse industry	
Less than 10 years	6 (21)
10-20 years	9 (31)
More than 20 years	14 (48)
Occupation	
Veterinarian/Laboratory	10 (34)
Veterinary nurse	7 (24)
Stud farm staff	12 (41)
Role	
Senior staff/Management role	17 (59)
General staff	12 (41)

230

231 ***Greater awareness of current and emerging infectious risks promotes use of PPE***

232 Most participants agreed that the use of PPE was motivated by awareness of infectious
233 risks. Some veterinarians believed a lack of risk awareness was a barrier to the use of PPE
234 on stud farms:

235 *There has been a level of complacency amongst our industry, and our profession*
236 *more specifically […] people have always felt some degree of comfort around the fact*
237 *that, "Well, they're animals." I've become much more aware of the One Health*
238 *perspective, and dealing with disease, the realisation that infections in one area are*
239 *going to mean infections [in another].* (Veterinarian, I-0018V)

Increased awareness was often driven by experience of zoonotic illness either personally or in close networks. Conversely, a lack of recent or personal experience with zoonoses was thought to contribute to decreased perception of risk.

> *I knew both the vets that died of Hendra virus. That makes a difference when they're people you'd had conversations with.* (Veterinarian, I-0021V)

> *They* [other veterinary nurses] *don't think it could affect them, and they don't know about how severe it could make them sick and that kind of thing. "Oh, it won't happen to me," type of thing, because we haven't had a lot of instances, it's not something that happens every day.* (Veterinary nurse, FG-0024VN2)

Several participants described a general shift in PB practices over the past decade. In particular, the emergence of HeV was described as an important turning point for practices within the industry.

> *Hendra virus changed a huge amount for us as equine clinicians…we were pretty slack before as far as doing minor procedures without gloves, where you actually did get bodily fluids and blood on your hands.* (Veterinarian, I-0022V)

However, there were conflicting opinions about the usefulness of 'scaring' people into using PPE.

> *If people knew more about it [equine chlamydiosis], and there was more cases actually proven, I think people might get a bit of a scare. But until you get to that point, I think people are going to brush it off.* (Foaling staff, FG-0027FS1)

> *Some of its just time and awareness and vet schools teaching appropriate practice - you can't scare people, that just doesn't work. I don't think so.* (Veterinarian, I-0021V)

In relation to the theme of personal knowledge and awareness, two main strategies were identified for improving awareness and uptake of PB. These were regular education and

training (particularly for new staff), and taking a proactive (rather than reactive) approach in recognising and responding to potential zoonotic risks.

> *For us to be fully competent in wearing PPE, putting it on, wearing it, taking it off safely, it actually takes a lot more training than just one or two goes at it. […] Doing it once a year is not enough.* (Laboratory staff, I-0016L)

> *Providing educational resources to equine vets, to show people what we should be doing to protect ourselves and alert people to the issues that are looming on the horizon […] antimicrobial resistance and emerging diseases, 75% of which are zoonotic, we have to be far more proactive in looking after ourselves. I feel very strongly about it.* (Veterinarian I-0018V)

Currently available PPE is not comfortable, practical or well-suited to equine reproductive work in Australia's hot climate

The discomfort and impracticality of currently available PPE, in particular P2/N95 masks and gowns, was universally described as a major barrier to its uptake, particularly in an outdoor environment, where most of the foaling occurs. Participants described the discomfort of conducting equine procedures while wearing PPE in the heat of the Australian climate:

> *I recall flushing a foal's joint outside of isolation on a mat once and it was a thousand degrees; we had pools of sweat in our gowns, it is thoroughly uncomfortable. No one likes wearing them; I get that, I really do.* (Veterinary nurse I-0015VN)

> *[…] it was a controlled vaginal delivery but it was taking a long time and the veterinarian that was helping started off a few minutes and then the mask went up on top of their head because you're huffing and you're puffing and you're burning a lot of energy. They're only as good as if you wear them so we need a system that's actually user friendly and you can leave it on and still do your job.* (Veterinarian FG-0029V1)

One participant observed that most available PPE had been designed for use in indoor, air-conditioned environments and was not well suited to the outdoor equine context.

> *The logistics are just a bit different to a human health setting…. Having to deal with contaminated bedding and things like that is a whole different scale to human health. It's quite difficult in cases where we've had a suspect positive Hendra horse, we've had to suit up in Tyvek suits with P2 masks in 40 degree heat.* (Laboratory staff I-0016L)

Others raised concerns that available PPE was a potential obstacle to conducting reproductive procedures (such as foaling a mare, performing uterine lavage (flushing), removal of retained products of conception, examination and disposal of fetal membranes, neonatal resuscitation) effectively, and could in some instances increase the risk of occupational injuries.

> *My experience is that if you're foaling a mare and it's a difficult foaling, if you need to manipulate the foetus, the foal, it's very, very difficult when you've got gloves on. Very difficult.* (Foaling staff FG-0026FS1)

> *I do have a problem with those* [shielded] *face masks and I don't wear them because I can't see. […] At this point for me personally if the mare is physically well and appears like a normal horse I don't wear it because I think my risk of getting kicked is higher than me getting Hendra.* (Veterinarian FG-0029V2)

Foaling a mare was frequently described as a time-critical or emergency situation ("an explosive event"), where concern for the horse's welfare often superseded consideration of personal safety or PPE.

> *I'm pretty sure from memory that [we] were quite concerned on the state of this foal, and pretty much dived on it and may have forgotten our masks at that stage.* (Veterinarian I-0019V)

That the PPE ends up being quite low on the priority list, as opposed to […] looking after one of the animals, probably the foal. (Veterinarian FG-0029V2)

In response to these barriers, participants had implemented a range of solutions to improve the practicality of PPE, such as double-gloving with a short nitrile glove to improve fit and grip of the polyurethane shoulder gloves; or using fabric coveralls (similar to hospital scrubs) to overcome the rustling of disposable gowns that may "spook" a horse. Simple solutions had been employed such as ensuring an adequate range and sizing of PPE was available.

I've been through scores of different types of P2 masks to make an appropriate fit, because […] if it doesn't feel comfortable, for somebody to spend at least two hours in, because that's how long a foal consult takes usually, if they [veterinary clinic staff] *aren't comfortable in wearing that, there really is no point. They just won't put it on even though they know what the risk is*. (Veterinary nurse I-0015VN)

Creating supportive environments for personal biosecurity reduces risk of exposure to infectious materials

Many participants who self-reported good uptake of PPE attributed this to employing a systematic approach to PB and BS in the workplace. Some BS and PB strategies relied on elimination of infectious disease risks through the physical layout and operation of the farm, or limiting contact of people with sick animals.

The first thing we have is our systems. Every department has their own assigned equipment, vehicles and staff. The diseases and germs that [one staff member] has are staying with [her] because she's not moving. We don't have [another person] bring his germs from his snotty-nosed weanlings back to [someone else's] mares and foals […] We're not bringing old foal germs to young foals. I think that prevention is the biggest success. (Stud manager FG-0025S1)

> *…so rather than having every student on rotation have a listen to the* [neonatal] *foal with the rattly chest, we'll just make it the people who need to be there.* (Veterinarian I-0017V)

Participants frequently referenced administrative controls such as protocols and procedures. Supportive infrastructure and resources (such as kits containing all necessary PPE, readily available gloves, and trucks equipped with taps) were seen as critical to embedding PB protocols into routine practice.

> *There needs to be protocols in places so that it doesn't matter what the disease is, it doesn't matter what the exposure is, you're protected.* (Veterinarian I-0018V)

> *Isolation kits, abortion kits and there's a procedure printed and laminated in each bin so you know. People say they miss things or cut corners when they're under pressure. When you're under pressure it's great to have a laminated piece of paper just to make sure you are doing it all in a logical order.* (Foaling staff, FG-0025S2)

Some participants also described novel BS engineered solutions that are not currently in existence, such as a trailer designed to drain away infectious materials when conducting post-mortems, or installing a drainage outlet in the floor of hospital rooms that was adequately sized to conduct away large volumes of waste material without the need for direct contact. The development of rapid diagnostics (such as stall-side chlamydia testing) was also recommended as a means of more effectively tailoring BS and PB to each case.

Strong leadership is required to implement sustainable change in workplace culture and practices

In addition to the implementation of BS and PB systems and infrastructure, many participants identified the importance of leadership and workplace culture in driving behaviour change. Culture was expressed by one participant as "*the way we do things*", and by another as when "*people are comfortable doing it and other people expect it*".

It's very much the culture on this farm that it's not negotiable and everyone does it. It doesn't matter who you are or what you're doing, you always put your gloves on. (Foaling staff FG-0025S2)

Several participants stated that changing the behaviour of others was hard, with some expressing a perceived lack of authority to implement change, and that to effect lasting change, a bottom-up approach would not be sustainable.

A lot of them [stud staff] *either don't understand or they don't care, so I think they need a good talking to, I'm not that person though.* (Veterinary nurse I-0015VN)

I think [change] *has to come from the top. When you try and bring things in from the bottom you'll get a few that do it and then overall it doesn't. I do think the directors and owners of the practice need to be, but we have a large H&S [Workplace Health and Safety] department and as long as the directors support that, then that's a good place for it to come from too.* (Veterinarian I-0018V)

Managers and supervisors expressed a responsibility for the wellbeing of their staff and students, and the need to promote a workplace culture that includes use of PPE by everyone.

I'm a big believer in leading by example so if I'm not prepared to do something then I don't expect somebody else to. Making sure that if I'm going to tell them all to wear a mask, then I've got one on myself. (Veterinary nurse FG-0024VN1)

I guess, at the end of the day, the wellbeing of particularly everybody that you're working with has to trump all other considerations, to me, over and above even personal health and safety. […] in this space, where we've got residents to look out for, nurses and students, I think sending a message to them that it [personal biosecurity] *is about responsible conduct and attitudes around protecting our physical wellbeing is an important consideration.* (Veterinarian I-0017V)

There were mixed views on the impact of age and career length on work culture and personal behaviours. Some participants attributed increased age with improved PB practices (citing lack of knowledge, naivety, and self-consciousness as barriers for junior staff), whilst others associated it with poorer compliance.

> *[…] that old-school mentality of, "I don't need to do that. I've been foaling things for 20 years. I've never done it* [wear PPE]*, and I don't need to do it."* (Veterinary nurse FG0023VN1)

Policy and economic factors plays an important role in adopting BS and PB measures in the workplace

Finally, broader factors outside the control of the equine breeding industry (such as legislation, regulation, policy and economic drivers) were acknowledged as determinants of PB practices. For example, a major consideration among several of the veterinarians interviewed was the legal requirement to provide a safe workplace:

> *We're really aware of the legal implications so I think that cavalier attitude of "I can walk around this" is becoming less apparent. The legal implications of not following appropriate protocol are substantive and I think that is a driver.* (Veterinarian I-0017V)

Regulation was identified as a potential vehicle for effecting broader change:

> *I think that's hard, and I think it'll take time. Even with AIDS it took time for the medical profession for things to become standard, and then I think regulation made a difference.* (Veterinarian I-0021V)

Several participants also observed that industry knowledge, attitudes and practices in relation to PB had improved over their career.

> *When I first started, it was very, very different. There was not as much information or education available, so you just did what everyone else used to do, really. There*

was no set stuff in place. It's changed a lot […] there's definite protocols in place nowadays. I would say most people are aware of them. Maybe not all, but most. (Veterinary nurse I-FG0024VN)

The cost of consumables was raised briefly in two interviews but was not considered to be a major factor in this study.

Discussion

The key themes identified in this study are supported by previous research in this area. Awareness of the potential presence of infectious pathogens is required for an individual to perceive themselves to be at risk. Studies of Australian veterinarians and horse owners have found that awareness of disease reservoirs, nearby cases and postgraduate education were associated with both increased risk perception and use of protective measures such as PPE in the context of HeV (Mendez et al., 2014b; Mendez et al., 2017; Wiethoelter et al., 2017a). However awareness is just one component of risk perception and mitigation. In other studies, high levels of knowledge among farmers were not necessarily linked to high BS and PB compliance (Palmer et al., 2009), and PB compliance among veterinarians was found to increase only marginally with multimodal educational campaigns (Smith et al., 2013).

Risk-based decisions are made both at an individual level and within a broader social context (Slovic, 2011). At the individual level, protection motivation theory suggests that people protect themselves based on their appraisal of the threat and their ability to mitigate it (Rogers and Prentice-Dunn, 1997). Cognitive theories of risk add that threat appraisal may be influenced by heuristics and biases, such as perceiving events easily brought to mind as more likely than events not easily imagined, or feeling greater concern over problems with an immediate or direct personal connection (availability heuristic) (Tversky and Kahneman, 1974). We found that participants weighed zoonotic risk in the context of other occupational risks (e.g. injury, heat stress). Those who believed they had contracted psittacosis were greater advocates for strong PB. However others reported neglecting PB in favour of the

more immediate/visible threat of injury. This is consistent with other studies of veterinary professionals and mirrors findings in human healthcare, where workers have been shown to be more careful in handling sharps than in taking basic precautions against the more likely, but less visible, risk of infectious diseases (Nicol et al., 2009; Mendez et al., 2014b; Willemsen et al., 2019).

We found social factors (such as social/professional roles and identity) and social norms (such as workplace culture), to be important drivers of risk perception and protective behaviour in our study. Social factors associated with PB practices in other studies include work culture (Anderson et al., 2014; Mendez et al., 2014b; Willemsen et al., 2019), rural culture and attitudes (Mendez et al., 2017), and concerns regarding negative client perception (Dowd et al., 2013b; Robin et al., 2017). Work culture, leadership and social cohesion have also been identified as critical factors in the uptake of hand hygiene strategies among healthcare workers (Kwok et al., 2017). There is growing evidence that a "patient safety climate" in healthcare organisations is associated with greater adherence to standard precautions (Hessels and Larson, 2016). This represents a potentially important lever for behaviour change within organisations such as stud farms and veterinary practices.

In addition to the parallels identified between this study and prior research, a number of novel findings emerged. The importance of the physical environment as a key barrier to use of PPE was a prominent feature of this study, and may be specific to the Australian context. PB measures were shown in one other study to vary by setting in veterinary practice, with more stringent PB practiced in clinic procedural areas (Smith et al., 2013). Farm participants in our study provided the additional insight that most PPE had been designed for a human healthcare setting and was therefore not well-suited to the often hot, outdoor environment of an Australian farm or veterinary clinic.

The time critical nature of foaling work also brings to bear findings from OHS in other emergency workers. "Goal seduction" is a term used to describe the motivation to forfeit safety behaviours for a productivity goal (such as getting somewhere on time or being paid),

466 which has been observed in studies of firefighters (Maglio et al., 2016). We found similarly
467 that first responders to obstetric emergencies such as veterinary nurses and stud personnel
468 often prioritised the safety of the mare and foal over their own. Participant behaviour also
469 reflected the phenomenon of “situation aversion”, where workers avoid safe choices due to
470 inconvenience or discomfort, or a perception that it would make them less accepted in their
471 workgroup. These findings further highlight the importance of organisational culture in
472 enabling routine practice of PB in this occupational group.

473 Career length was identified by several participants as a determinant of PB practice and
474 workplace culture. Participants in our study who believed PB practices to be poorer in older
475 veterinarians attributed this to resistance to change and historical “habits”, believing younger
476 veterinarians had been trained to be more proactive and had an increased awareness of
477 emerging risks. This is in contrast to the findings of another study where final year veterinary
478 students and early career veterinarians lacked experience and confidence implementing PB
479 measures (Mendez et al., 2014b; Mendez, 2016)..

480 Our study suggests that the broader culture of PB within the Thoroughbred breeding industry
481 is changing. PB can be conceived of within a Hierarchy of Controls framework (Figure 1.)
482 (NIOSH, 2013; Australian Veterinary Association, 2017). This framework of occupational
483 hazard management spans “elimination, substitution, engineering controls, administrative
484 controls and personal protective equipment,” from most effective to least on the BS
485 continuum. The strategies and structures to improve PB uptake described by our participants
486 had moved beyond reliance on PPE alone and included administrative controls (protocols,
487 policies, procedures) engineering controls (e.g. clinic room or farm design), and hazard
488 elimination (restricting the number of people involved in management of a potentially
489 infectious case). This suggests progress has already been made in OHS in the industry,
490 particularly since the emergence of HeV.

491 Finally, leadership and the use of existing management structures were identified by
492 participants as an important mechanism for changing behaviour. A cornerstone of these

493 structures was a program of regular PB education and training, as well as its integration into
494 orientation training for new employees. This is consistent with previous research that has
495 identified PB policies, management support and staff member support as important drivers
496 of PB practice (Mendez, 2016; Willemsen et al., 2019). Veterinary nurses identified
497 veterinarians and workplace protocols as key sources for their PB information in this study
498 and others (Sellens et al., 2016); farm participants also reported heavy reliance on protocols
499 in the stud farm setting. The Hierarchy of Controls approach, which sits within a broader
500 initiative of Prevention through Design, could provide a useful structure for stud and
501 veterinary practice managers to integrate BP into their organisational policies (Australian
502 Veterinary Association, 2017).

503 This study has important strengths. It is the first study to examine PB in the Thoroughbred
504 breeding industry, and includes the under-studied groups of stud farm employees and
505 veterinary nurses. We also chose a strengths-based approach, exploring not only barriers
506 but also solutions generated from within the participant groups. Employing a qualitative
507 approach enabled a deep understanding of the multiple factors affecting behaviour in a real-
508 world setting. The cross-disciplinary nature of the research team, spanning human and
509 animal health, clinical and academic expertise, offered a unique one health perspective on
510 all aspects of the study.

511 The study has some limitations. We explored the views and experiences of participants in
512 select breeding communities and so the findings/results may not apply in other contexts. As
513 we used purposive sampling in a range of equine settings in NSW, our results will be of
514 interest to others working in similar settings. Participants were invited from areas that
515 experienced recent epizootics of equine chlamydiosis and so may have been more vigilant
516 with PB practices, compared to those in other settings. These participants were purposively
517 selected in order to identify strategies for improving PB. The interviewers (KT and ST) were
518 human rather than veterinary healthcare professionals and may have lacked an insider's
519 understanding of some concepts that emerged from the data. We sought veterinarian input

on the interview framework and clarification from participants during data collection. One researcher involved in the study design and data analysis (DM) was a veterinarian and further clarified content in the transcripts.

Conclusions

Personnel working in the Australian Thoroughbred breeding industry face unique zoonotic risks in a challenging physical environment. A qualitative approach provided deeper insights into social and physical factors motivating PB in this occupational group. Ongoing collaboration with industry is needed to translate research findings into practice. Future cross-disciplinary work could include developing evidence-based training resources; exploring safety solutions developed for occupations with similar environmental challenges such as fire-fighting (e.g. cooling, fatigue management); and incorporating Prevention through Design principles into clinic and farm management. Appropriate policies and legislation are required to ensure workplace safety and adoption of guidelines. This research identified a number of opportunities for Public Health services and industry partners to collaborate and implement strategies most likely to be effective in ensuring infection prevention and control is used by everyone, every time.

Acknowledgements

This project was supported in part by the CSIRO (Innovation Connections Grant ICG000396) and in part by the New South Wales Ministry of Health Prevention Research Support Program.

References

Anderson, M.E., Sargeant, J.M., Weese, J.S., 2014. Video observation of hand hygiene practices during routine companion animal appointments and the effect of a poster intervention on hand hygiene compliance. BMC veterinary research 10, 106.

Anderson, M.E.C., Weese, J.S., 2016. Self-reported hand hygiene perceptions and barriers among companion animal veterinary clinic personnel in Ontario, Canada. Can Vet J 57, 282-288.

Australian Veterinary Association, 2017. Guidelines for Veterinary Personal Biosecurity. In: AVA (Ed.) Australian Veterinary Association, Sydney.

Balzer, M., 2015. Work health and safety concerns over Hendra virus. Australian veterinary journal 93, N21.

Chan, J., Doyle, B., Branley, J., Sheppeard, V., Gabor, M., Viney, K., Quinn, H., Janover, O., McCready, M., Heller, J., 2017. An outbreak of psittacosis at a veterinary school demonstrating a novel source of infection. One Health 3, 29-33.

Christley, R., Perkins, E., 2010. Researching hard to reach areas of knowledge: qualitative research in veterinary science. Equine Veterinary Journal 42, 285-286.

Dowd, K., Taylor, M., Toribio J, Hooker, C., Dhand, N., 2013a. Zoonotic disease risk perceptions and infection control practices of Australian veterinarians: Call for change in work culture. Preventive Veterinary Medicine 111, 17-24.

Dowd, K., Taylor, M., Toribio, J.A., Hooker, C., Dhand, N.K., 2013b. Zoonotic disease risk perceptions and infection control practices of Australian veterinarians: call for change in work culture. Preventive veterinary medicine 111, 17-24.

Hessels, A.J., Larson, E.L., 2016. Relationship between patient safety climate and standard precaution adherence: a systematic review of the literature. The Journal of hospital infection 92, 349-362.

566 Jenkins, C., Jelocnik, M., Micallef, M.L., Galea, F., Taylor-Brown, A., Bogema, D.R., Liu, M.,
567 O'Rourke, B., Chicken, C., Carrick, J., Polkinghorne, A., 2018. An epizootic of Chlamydia
568 psittaci equine reproductive loss associated with suspected spillover from native Australian
569 parrots. Emerging microbes & infections 7, 88.

570 Kung, N., McLaughlin, A., Taylor, M., Moloney, B., Wright, T., Field, H., 2013. Hendra virus
571 and horse owners--risk perception and management. PloS one 8, e80897.

572 Kwok, Y.L., Harris, P., McLaws, M.L., 2017. Social cohesion: The missing factor required for
573 a successful hand hygiene program. American journal of infection control 45, 222-227.

574 Larter, N., Stow, R., 2017. Psittacosis: An emerging infectious disease investigated in a
575 Rural Veterinary School within the Murrumbidgee Local Health District of NSW. Public
576 Health Association of Australia Communicable Diseases Conference 2017. Melbourne,
577 Australia.

578 Maglio, M.A., Scott, C., Davis, A.L., Allen, J., Taylor, J.A., 2016. Situational Pressures that
579 Influence Firefighters' Decision Making about Personal Protective Equipment: A Qualitative
580 Analysis. American journal of health behavior 40, 555-567.

581 Mendez, D., Buttner, P., Speare, R., 2014a. Hendra virus in Queensland, Australia, during
582 the winter of 2011: Veterinarians on the path to better management strategies. Preventive
583 Veterinary Medicine 117, 40-51.

584 Mendez, D.H., 2016. Identifying and understanding the factors affecting infection control and
585 Hendra virus risk management in private veterinary practices in Queensland, Australia.
586 James Cook University, Townsville.

587 Mendez, D.H., Buttner, P., Kelly, J., Nowak, M., Speare Posthumously, R., 2017. Difficulties
588 experienced by veterinarians when communicating about emerging zoonotic risks with
589 animal owners: the case of Hendra virus. BMC veterinary research 13, 56.

590 Mendez, D.H., Kelly, J., Buttner, P., Nowak, M., Speare, R., 2014b. Management of the
591 slowly emerging zoonosis, Hendra virus, by private veterinarians in Queensland, Australia: a
592 qualitative study. BMC Vet Res 10, 215.

593 National Health and Medical Research Council, 2019. Australian Guidelines for the
594 Prevention and Control of Infection in Healthcare. In: NHMRC (Ed.) NHMRC, Canberra.

595 Nicol, P.W., Watkins, R.E., Donovan, R.J., Wynaden, D., Cadwallader, H., 2009. The power
596 of vivid experience in hand hygiene compliance. The Journal of hospital infection 72, 36-42.

597 NIOSH, 2013. The state of the national initiative on prevention through design. In: National
598 Institute for Occupational Safety and Health (Ed.) U.S. Department of Health and Human
599 Services, Centers for Disease Control and Prevention, Cincinnati, OH.

600 Palmer, S., Fozdar, F., Sully, M., 2009. The Effect of Trust on West Australian Farmers'
601 Responses to Infectious Livestock Diseases. Sociologia Ruralis 49, 360-374.

602 Robin, C., Bettridge, J., McMaster, F., 2017. Zoonotic disease risk perceptions in the British
603 veterinary profession. Preventive veterinary medicine 136, 39-48.

604 Rogers, R.W., Prentice-Dunn, S., 1997. Protection motivation theory. Handbook of health
605 behavior research 1: Personal and social determinants. Plenum Press, New York, NY, US,
606 113-132.

607 Sellens, E., Norris, J.M., Dhand, N.K., Heller, J., Hayes, L., Gidding, H.F., Willaby, H., Wood,
608 N., Bosward, K.L., 2016. Q Fever Knowledge, Attitudes and Vaccination Status of Australia's
609 Veterinary Workforce in 2014. PloS one 11, e0146819.

610 Slovic, P., 2011. The Feeling of Risk: New Perspectives on Risk Perception. Energy &
611 Environment 22, 835-836.

612 Smith, J.R., Packman, Z.R., Hofmeister, E.H., 2013. Multimodal evaluation of the
613 effectiveness of a hand hygiene educational campaign at a small animal veterinary teaching
614 hospital. Journal of the American Veterinary Medical Association 243, 1042-1048.

615 Taylor, K.A., Durrheim, D., Heller, J., O'Rourke, B., Hope, K., Merritt, T., Freeman, P.,
616 Chicken, C., Carrick, J., Branley, J., Massey, P., 2018. Equine chlamydiosis-An emerging
617 infectious disease requiring a one health surveillance approach. Zoonoses and public health
618 65, 218-221.

619 Thoroughbred Breeders Association, 2019. Thoroughbred Breeders Association.

620 Tversky, A., Kahneman, D., 1974. Judgment under Uncertainty: Heuristics and Biases.
621 Science (New York, N.Y.) 185, 1124-1131.

622 Weese, J.S., 2014. Infection control and biosecurity in equine disease control. Equine
623 Veterinary Journal 46, 654-660.

624 Wiethoelter, A.K., Sawford, K., Schembri, N., Taylor, M.R., Dhand, N.K., Moloney, B.,
625 Wright, T., Kung, N., Field, H.E., Toribio, J., 2017a. "We've learned to live with it"-A
626 qualitative study of Australian horse owners' attitudes, perceptions and practices in response
627 to Hendra virus. Prev Vet Med 140, 67-77.

628 Wiethoelter, A.K., Schembri, N., Dhand, N.K., Sawford, K., Taylor, M.R., Moloney, B.,
629 Wright, T., Kung, N., Field, H.E., Toribio, J., 2017b. Australian horse owners and their
630 biosecurity practices in the context of Hendra virus. Prev Vet Med 148, 28-36.

631 Willemsen, A., Cobbold, R., Gibson, J., Wilks, K., Lawler, S., Reid, S., 2019. Infection control
632 practices employed within small animal veterinary practices-A systematic review. Zoonoses
633 and public health 66, 439-457.

634 Wright, J.G., Jung, S., Holman, R.C., Marano, N.N., McQuiston, J.H., 2008. Infection control
635 practices and zoonotic disease risks among veterinarians in the United States. Journal of the
636 American Veterinary Medical Association 232, 1863-1872.

637