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Perceptions of dog owners towards canine gastrointestinal parasitism and associated human health risk in Southeast Queensland

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ABSTRACT

Canine companion animals can carry a number of zoonotic parasites which can adversely impact both human and animal health. Previous studies in Australia indicated that while parasitic infections in dogs are still common and there is variability in the awareness and perception of zoonotic risks among pet owners, the likely contribution of sociodemographic factors to the variation in awareness and perception needs to be further explored. The primary objective of this study is to quantify the relationship between dog owners' knowledge and beliefs about dog parasites and their sociodemographic characteristics. In this study, we surveyed a total of 281 dog owners in SE Queensland between April 2019 to March 2020 and the relationship between dog owners' perception of gastrointestinal parasite infection was assessed using an adaptation of the Health Belief Model, social cognitive framework for health protection. The model looked into the role of dog owners' demography on their perceived severity and susceptibility to zoonotic canine parasites and their likelihood of performing actions associated with worm control of their pets. Our results indicate that owners perceptions about parasitic disease severity in their pets was 26% higher in female dog owners compared to males, in respondents owning dogs over 10 years (27% higher than those owning a dog <3 years) and those owners that regularly deworm their pets and report faeces disposal. Our study indicates that the perceptions of pet owners towards zoonotic canine parasites varies demographically and owner education is important to prevent infection among dogs and control the zoonotic transmission to owners and the community. Finally, there was evidence that increased frequency of visits to veterinary clinics can increase the likelihood of owners performing worm treatment, proper faecal disposal, and cooking meat before feeding it to dogs.

1. Introduction

Dogs play an important role in society, enhancing the psychological and physiological wellbeing of individuals. Australia has one of the highest rates of pet ownership in the world with 62% of Australian households owning pets and it is estimated that there is a total of 4.8 million domestic dogs (20 per 100 people) in Australia corresponding to 1.3 dogs per household [1].

As with other animal species, dogs can be infected with gastrointestinal (GI) parasites, which not only affect their health and wellbeing but also the health of owners and the community if not well managed [2]. Children especially under 10 years of age are at greater risk because of lower levels of hygiene and the habit of pica or geophagia [3]. While most transmission of zoonotic GI infections of dogs occurs in the household, dog faeces in public places, such as parks, children's playgrounds and beaches can serve as a potential source of viable zoonotic GI parasites to the community [4,5].

Gastrointestinal parasites of dogs of public health importance in Australia are round worms *Toxocara canis,* hookworms *Ancylostoma* spp. and *Uncinaria* spp., and the tape worm *Echinococcus* sp., the prevalence of which varies with ownership characteristics, geographical conditions and communities' perceptions of risk [6]. In Australia, the prevalence of *T. canis* in refuge dogs was found to be higher (2.4%) than that of owned pets attending veterinary clinics (0.4%) [7], it was estimated to be 3.1%

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in rural dogs in the eastern states of mainland Australia and Tasmania [8], 2.8% in rural shelters [6] and highly prevalent in domestic dogs in and around Aboriginal Communities in the Wet Tropics of north-eastern Queensland [9]. Similarly, in the case of *Echinococcus* sp. a recent study indicated that more than half of the wild peri-urban dog population in South East Queensland are infected with *E. granulosus* [10], potentially exposing the pet dog population to infection.

Pet ownership has been demonstrated to constitute an important risk factor for human infection with zoonotic parasites [11]. Indeed peoples' decisions for their own health as well as the wellbeing of their animals are influenced by their disease risk perceptions and relevant health actions. Since treatment and control of parasite infection in pets like other pet care entirely depends on their owners, it is essential to learn about the factors associated with the perception of pet owners about zoonotic parasitic disease and their beliefs on the benefits of pet parasite control.

Measurement of individual's behaviours towards disease prevention is complex and often requires social cognitive models that harness conceptual relationships between perceptions and health action. One such model is the Health Belief Model (HBM), which has been used widely in human medicine [12]. The HBM was developed by social psychologists in the U.S. Public Health Service in the 1950s to explain low levels of participation in a tuberculosis screening program [13,14] and has been widely used since then. The HBM hypothesizes that health-related action depends on the concurrent occurrence of three classes of factors [15]. Firstly, the existence of sufficient motivation (or health concern) to make health issues significant or relevant, this is termed as perceived susceptibility. Secondly, the belief that one is susceptible to a particular health problem or to the subsequent illness or condition, termed as perceived threat. Thirdly, perceived benefit is the belief that following a particular health advice would be beneficial in reducing the perceived threat, at a subjectively acceptable cost. Here cost refers to perceived barriers that must be overcome in order to follow the health recommendation.

Although the HBM model has been utilised widely and successfully in human medicine; its use in veterinary medicine has been limited. In the veterinary context HBM has been used in Dutch fattening pig farms [16], to investigate farmers' perceptions towards animal disease risks and animal health risk management and the factors determining farmers' adoption of biosecurity measures and animal health programs risk management strategies. In another study the Health Belief Model was used to look into the attitudes of horse owners in the UK towards worm egg counts and targeted selective treatment against small strongyles in horses [17]. Looking into the wide applications of HBM in human medicine and growing applications in the veterinary field, HBM is a useful tool for the field of veterinary medicine as it can elucidate the levels of perception of owners towards pet health, particularly preventive measures and treatment which in turn influence their decisions about pet health care. Furthermore, a social cognitive model such as the HBM can identify factors associated with pet owners' health behaviours. Hence, measuring the effect size of each of the HBM components can be used to design health promotion campaigns, which in turn help raise awareness and encourage people to employ appropriate preventive actions and treatments.

This study aims to deploy a modified HBM to evaluate the association between dog owner's likelihood of performing preventive measures towards their dog's gastrointestinal infections (providing worm treatments, cooking meat before feeding the dogs, and disposing dog faeces appropriately) and their risk perceptions and demographic factors (age, gender, education, residence urbanisation and duration of dog ownership) in South East Queensland, Australia.

2. Methods

2.1. Ethical statement

Human ethic approvals were given by the Human Ethics Committees and Animal Research Ethics Committees of the University of Queensland (Approval Number: 2019999965). Distribution of survey and brochures in dog parks were approved by the Brisbane City Council prior to data and sample collection. All participants were asked for their consent to provide personal data for this study before proceeding to completion of the survey.

2.2. Study setting and selection of study sites

Our investigation targeted the owner population of the state of Queensland, Australia, where approximately 38% of households own at least one dog, translating to an owned dog population in Queensland of at least 629,596 in 2016 (Animal Medicine Australia, 2016). Moreover, about 70% of Queensland human population are concentrated in the region of South East Queensland (SEQ) [18]. Hence, it is expected that most Queensland owned dog population are located within SEQ. One interesting aspect of this region is its large variation in outdoor habitat types: a high level of urbanisation exists along the coastal areas while a large part of SEQ's inland areas are used for agriculture or are covered by vegetation for conservation and forestry purposes [19]. Therefore, coastal cities scored significantly higher in socioeconomic level than inland rural areas [20]. Hence, these factors make SEQ an interesting site of study of dog parasites as well as the pet ownership. Previous studies have reported incidence of zoonotic parasites among the owned dogs in SEQ and zoonotic hookworms *Ancylostoma ceylanicum* in domestic dogs in Brisbane and Sunshine Coast [11].

Off-leash dog parks within metropolitan Brisbane were chosen as the sites of investigation due to their popularity among locals. A georeferenced list of 145 dog parks within a total of 59 postcodes in Brisbane City Council were provided by the Brisbane City Council. After that, binned variables representing socioeconomic index and ratios of human population to dog registrations were created using the 2016 Socio-Economic Indexes for Areas (SEIFA) metric and the 2016 ABS Australian Census from the Australian Bureau of Statistics (ABS). After that, stratified sampling was used to create the target survey area consisting of 45 parks with equal representations of each variable combination. Between 20th April 2019 to 21st March 2020, 39 dog parks out of 45 were visited for data collection.

2.3. Health belief model (HBM) of zoonotic risk of dog gastrointestinal infection

For our study, we utilised a modified HBM model (Fig. 1) for assessing the role of four factors that are believed to influence the decisions of owners towards the prevention of parasites in their dogs [13] namely Perceived susceptibility (The belief of the probability or likelihood of dogs and humans contracting zoonotic parasitic infection); Perceived severity (The belief of the seriousness of zoonotic parasitic infection in dogs and humans when contracted or left untreated); Perceived benefits (The belief of the positive impacts of health-related behaviours on reducing the risk or severity of zoonotic parasitic infection in dogs); Perceived barriers: Factors or beliefs that prevent an individual from seeking or performing health-related behaviours towards their dogs.

We modified the HBM by separating it into two interlinking steps. In the first step, we built a model of owner's perceived severity of GI parasite infection, which combined the demographic data (age, level of education, duration of dog ownership, and residence-urbanisation) and owner's perceived susceptibility to GI parasites (Model 1). The residuals from the analysis of Model 1 can be thought of as the unexplained variation in a pet owner's perceived severity of parasite infection. Next, we built a model that estimates, the likelihood of action based on perceived seriousness, benefits-barriers and health motivation factors (Model 2), which combines residuals from Model 1 and perceived benefits minus perceived barriers, and some health motivation factors (pet insurance and veterinary visitation frequency) on the likelihood of a pet

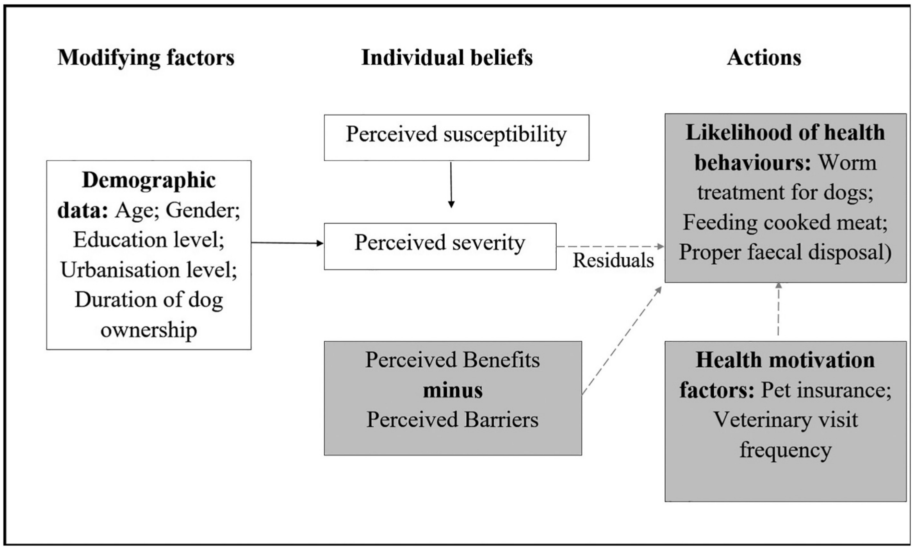

Fig. 1. The modified HBM used for data analyses. Solid arrows represent Model 1 analyses. Dashed arrows represent Model 2 analyses.

owner taking health related actions (such as using preventative worm treatments).

2.4. Data collection

An online questionnaire survey was developed via the website SurveyMonkey (https://www.surveymonkey.com/r/petparaware). The survey was distributed in the form of brochures and posters, with links and QR codes of the survey printed on these small media to allow responders to fill in the survey on their own mobile devices. The dog parks were visited in the late afternoon for 2–3 h for the distribution of the survey. The participants were asked to do the survey prior to reading the information in brochures to minimise bias. At the beginning of the study, about 6–8 volunteers participated during sampling sessions of each park visit, but in later samplings the number of volunteers reduced to 1–2, mainly due to study and work commitments of the volunteers.

The survey included a questionnaire comprising three sections: the first section of questions collected information about owners' demography (age, highest level of education, gender, and duration of pet ownership). It was expected that these factors were the key indicators of the perceived severity of owners about dog parasites. These demographic variables allowed us to investigate and adjust for known confounders that may influence the perceived severity of respondents about dog GI parasites. The second section focused on questions that related to the main outcome of our modified-HBM including types of behaviours that dog owners employ to prevent parasitic infection in dogs, allowing us to understand how the perceptions of owners influence the decisions for their pet health care. These included questions related to parasitic worm treatment (frequency and product used), the dog's diet (whether raw meat was fed), and owner investment in veterinary care (veterinary visitation frequency and whether pet insurance was purchased). The third section of the questionnaire focused on the awareness of owners about dog parasites using a set of 23 Likert-format questions, 21 of which were used to populate predictor data of our modified-HBM (Table 1). These questions were formulated to evaluate the perception of respondents towards parasites and relevant control measures, including statement such as "I am aware of the parasites which affect dogs", "I am aware that some of these parasites can infect humans", "I treat my dog(s) regularly for worms", "Regularly treating dogs against worms will protect them from parasite infestation", and "It's physically difficult to give dewormer to dogs". Participants were asked to rate their agreement to each statement on a five-level scale (1 = Strongly disagree, 2 = Disagree, 3 = No opinion/Unsure, 4 = Agree, 5 =

Table 1
Survey questions included in the Health Belief Model.

Survey item	Average response
Perceived Susceptibility	
- My property and its surroundings have high-risk areas for parasite infestation	2.68
- Access to wildlife, or visit to places with wildlife increases a dog's risk of acquiring parasites	3.76
- Keeping pets indoors would help prevent them acquiring parasites	3.30
Perceived Seriousness	
- I am aware of the parasites which affect dogs	3.82
- I am aware parasite worms causes disease in dogs	4.32
- I am aware that dog poo contains parasite eggs	3.88
- I am aware dogs can get infected with parasites from the environment	4.23
- I am aware that some of these parasites can infect humans	3.86
- I am aware that raw meat may contain parasites which can infect dogs	3.66
- There is a risk that dogs could acquire parasites which I might accidentally carry into my home	3.58
- I would be concerned about my pet acquiring worms	3.86
Perceived Benefit	
- I am aware that without regular deworming, dogs would be at risk of acquiring parasite infection	4.56
- Regularly treating dogs against worms will protect them from parasite infestation	4.33
- It's important that pets have access to the outdoors, even if they could be exposed to parasites	4.46
Perceived Barriers	
- The cost of parasite worm prevention outweighs the benefits of regularly using it	2.26
- Dog doesn't like worm treatments	2.52
- It's physically difficult to give dewormers to dogs	2.25
- It's hard to remember to give treatment to dogs at the recommended frequency	2.43
Actions	
- I treat my dog(s) regularly for worms	4.47
- I always make sure dog poo is disposed properly	4.24
- I always make sure to cook the meat before feeding it to dogs	2.73

Strongly agree). A pilot survey was first run within the group of volunteers and researchers to refine the questions. This pilot was rolled out via email to staff and students of the School of Veterinary Science at University of Queensland as well as to the general public through a field test at Carindale Recreational Reserve in Brisbane. The survey questions were modified and re-worded based on the feedback of respondents and the time of park visit was adjusted to maximise data collection.

2.5. Data analyses

All statistical analyses were conducted using the open-source software R (version 3.6.1) in the RStudio environment. The analysis of the different sections of our modified HBM model was performed in two interlinked steps. First, Model 1 utilised a multivariable linear regression to measure the association between owner's perceived severity of parasite infection (outcome of interest included as a continuous variable capturing the average of 8 Likert questions related to perceived severity (Table 1) and demographic factors (age, level of education, duration of dog ownership, and residence urbanisation) and owner's perceived susceptibility to parasites (Table 1). In addition, simple univariable linear regressions were also applied for each predictor variable alone for comparison purposes and to better explore their effects.

Second, Model 2 was developed to measure the association between the probability of owners' adopting preventative measures against the parasite infection and impacts of perceived severity (residuals from Model 1), perceived benefits minus perceived barriers, and some health motivation factors (pet insurance and veterinary visitation frequency). The residuals of Model 1, which captured the fraction of owners' perceptions of severity that was not explained by confounding demographic factors were used as a predictor variable in a second model. Ordinal logistic regression was used for this analysis since the dependent variable, or the preventive measures, were ordinal Likert variables ranging from 1 to 5. In addition, the independent variables (perceived severity, perceived benefits, and health motivation factors) were all either ordinal or categorical variables. By using ordinal regression with a logit link function, we assumed effects of regressors were represented as proportional odds, which means each independent variable had the same effect size at each cumulative split of the ordinal dependent variable. Finally, two other secondary models were formed by replacing worm treatment with the likelihood of proper faeces disposal in community waste disposal bins and the likelihood of feeding cooked meat as the ordinal responses.

3. Results

3.1. Dataset for analysis

A total of 39 dog parks were sampled and 281 responses were collected during the study (Table 2). The majority of the participants were female ($n = 186$), between 26 and 45 years of age ($n = 149$), had completed Bachelor or Diploma degrees ($n = 156$), lived in the suburban areas ($n = 205$), or had owned a dog for over 10 years ($n = 134$). Fewer respondents were male ($n = 93$), between 18 and 25 years old ($n = 22$) or lived in rural areas ($n = 19$) (Table 2). There was consistency in the mean perceived benefits and perceived barriers. In all demographic categories, the mean score for perceived benefits remained relatively high (above 4); while that of perceived barriers only ranged between 2.2 and 2.6 (Table 2). In addition, 65.4% of respondents ($n = 184$) had fed raw meat to their dogs, while 98.2% ($n = 276$) had provided anthelmintic treatments.

3.2. Association between perceived severity and demographic and perceived susceptibility factors (model 1)

For the analysis of the HBM, 271 survey responses were eligible for data analysis (the remaining 10 responses contained missing information in at least one question) (Table 3). The R2 of this model was 0.20, which indicates that the demographic factors and perceived susceptibility explained about 20% of the observed variance in perceived severity. Our results indicated that perceived severity of GI parasites was significantly and positively associated with perceived susceptibility and the owner's gender and duration of dog ownership (Table 3). Of particular interest was the score for perceived severity of female respondents, which was 25% (OR = 1.26, 95% CI = 1.06–1.48, $p < 0.01$, Table 3) greater than that of males. Respondents who owned dogs for more than ten years showed a 27% (OR = 1.27, 95% CI = 1.04–1.55, $p < 0.05$; Table 3) higher perceived severity of parasite infection compared to those who owned dogs for 0–3 years. Finally, both univariable and multivariable analyses showed positive effects of perceived susceptibility on perceived severity (OR = 1.51, 95% CI = 1.33–1.72, $p < 0.001$; Table 3).

3.3. Likelihood of action based on perceived seriousness, benefits-barriers and health motivation factors (model 2)

Our results indicated that the probability of owners performing worm treatment was significantly and positively associated with the residuals from Model 1 (OR = 2.13, 95% CI = 1.28–3.58; Table 4) and the variable that captured the difference between the perceived benefits and barriers of worm treatment of pet dogs (perceived benefits – perceived barriers) (OR = 2.52, 95% CI = 1.93–3.33, $p < 0.001$). Our results also show that the probability of worm treatment is significantly associated with increasing number of visits per year (Table 4). In addition, our analysis suggests that the probability of owners cooking meat for their pets was significantly negatively associated with the variable that captured the difference between the perceived benefits and barriers

Table 2

Mean HBM outcomes (presented as mean score /5) and number of respondents for each demographic factor. Bold figures indicate highest value in each column.

Demographic		Number Respondents	Susceptibility	Severity	Benefits	Barriers
Age	**18–25**	22	**3.42**	**4.02**	**4.50**	2.41
	26–45	149	3.27	3.82	4.43	2.34
	46–60	71	3.20	3.97	4.48	**2.50**
	60+	38	3.11	4.00	4.42	2.24
Gender	**Female**	186	**3.27**	**3.98**	**4.51**	**2.37**
	Male	93	3.19	3.75	4.33	2.35
Education	**High school or Certificates**	61	**3.28**	**3.94**	4.41	**2.42**
	Bachelor or Diploma	156	3.24	3.89	4.40	2.41
	Postgraduate	60	3.21	3.86	**4.58**	2.21
Residence urbanisation	**Rural**	19	**3.54**	**4.21**	4.32	2.36
	Suburban	205	3.21	3.90	**4.46**	**2.40**
	Urban	57	3.27	3.81	**4.46**	2.27
Dog ownership	**0–3 years**	81	3.24	3.70	**4.47**	2.26
	3–10 years	66	3.23	3.88	4.37	**2.60**
	>10 years	134	**3.26**	**4.03**	**4.48**	2.32

Table 3
Univariable and multivariable results of regression model of perceived severity (Model 1). OR, Odds Ratio.

Variable		Univariable analysis		Multivariable analysis	
		OR (95% conf.)	*P* value	OR (95% conf.)	P value
Age	**26–45**	0.84 (0.60–1.18)	0.32	0.97 (0.70–1.34)	0.84
Baseline = 18–25 years old	**46–60**	0.94 (0.66–1.35)	0.75	1.03 (0.73–1.45)	0.86
	60+	0.96 (0.65–1.43)	0.85	1.15 (0.78–1.69)	0.47
Gender	**Female**	1.26 (1.05–1.50)	<0.05	1.25 (1.06–1.48)	<0.01
Baseline = Male					
Education	**Bachelor or Diploma**	0.94 (0.76–1.17)	0.58	0.98 (0.80–1.19)	0.81
Baseline = High school or Certificates	**Postgraduate**	0.97 (0.75–1.25)	0.79	1.0 (0.82–1.32)	0.76
Residence urbanisation	**Urban**	0.65 (0.45–0.93)	<0.05	0.80 (0.56–1.13)	0.21
Baseline = Rural	**Suburban**	0.73 (0.52–1.03)	0.072	0.94 (0.68–1.29)	0.71
Dog ownership	**3–10 years**	1.16 (0.92–1.46)	0.22	1.10 (0.87–1.36)	0.39
Baseline = 0–3 years	**10 years +**	1.40 (1.15–1.70)	<0.01	1.27 (1.04–1.55)	<0.05
Susceptibility		1.52 (1.34–1.73)	<0.001	1.51 (1.33–1.72)	<0.001

Table 4
Multivariable results of factors associated with different cues to action to control dog gastrointestinal parasitism (Model 2). OR, Odds Ratio.

Variables		Worm Treatment		Cooking meat		Proper faecal disposal	
		OR (95% CI,)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Model 1 residuals		2.13 (1.28–3.58)	<0.001	1.24 (0.84–1.84)	0.28	3.89 (2.45–6.28)	<0.001
Benefits - barriers		2.52 (1.93–3.33)	<0.001	0.83 (0.68–0.99)	<0.05	1.37 (1.11–1.68)	<0.01
Pet Health Insurance		1.40 (0.76–2.63)	0.28	1.32 (0.84–2.07)	0.23	2.44 (1.42–4.27)	<0.01
Baseline = no insurance							
Veterinary frequency	Once per year	2.65 (1.25–5.63)	<0.05	1.68 (0.84–3.38)	0.14	2.58 (1.24–5.36)	<0.05
Baseline = for emergencies only	Twice per year	3.15 (1.25–8.15)	<0.05	1.44 (0.66–3.17)	0.36	2.51 (1.08–5.92)	<0.05
	Three or more times per year	4.98 (1.69–16.09)	<0.05	2.29 (1.01–5.24)	<0.05	1.77 (0.73–4.32)	0.21

(perceived benefits – perceived barriers) (OR = 0.83, 95% CI = 0.68–0.99) and positively associated with owners that visit veterinary practices three or more times per year (OR = 2.29 95% CI = 1.01–5.24). The probability of disposing dog's faeces properly in community waste disposal bins was significantly and positively associated with the residuals of Model 1 (OR = 3.89, 95% CI = 2.45–6.28), the variable that captured the difference between the perceived benefits and barriers (perceived benefits – perceived barriers) (OR = 1.37, 95% CI = 1.11–1.68, $p < 0.01$), owners having health insurance for their pets (OR = 2.44, 95% CI = 1.42–4.27, $p < 0.01$). The probability of disposing dogs' faeces was equally likely for owners that visited a veterinary practice once and twice per year (OR = 2.58, 95% CI = 1.24–5.36 and OR = 2.51, 95% CI = 1.08–5.92, respectively).

4. Discussion

The current study investigated the role of the perception of dog owners in South East Queensland about their dogs' GI parasitism and the likelihood of performing preventative actions associated with worm control. In order to achieve the proposed aim, we developed a modified-Health Belief Model (HBM) [12] adapted to the problem of gastrointestinal parasitism of dogs, which has given important insights into the perceptions of dog owners towards GI parasitism and is a promising conceptual framework for future HBM studies for other companion animal health care problems.

4.1. Dog owner demography and perceptions towards dog GI parasitic infections

Our results indicate that owner's perceived severity in relation to their dogs gastrointestinal parasitism was associated with owner's gender, duration of dog ownership and perceived susceptibility. In our study we found a higher perceived severity of dog parasite infection among female owners compared to males which is on par with studies showing differences between genders with regards to awareness and perceptions of the risk of animal aggression towards children. For example, studies on dog aggression have found that women in general, were more aware than men of the potential dangers of dog aggression [21]. Similarly, a study on the likelihood of neutering pets in Australia, found that women were more willing to perform pet sterilisation and understood the associated benefits compared to men [22]. Our results also indicated that years of dog ownership increased the perceived seriousness towards pet parasites. It showed that owners who owned dogs for longer were more likely to be exposed to animal health information than new owners. A study from Canada found that pet owners were more knowledgeable about zoonoses associated with their animals than the non-pet owning respondents [23]. A similar survey on the awareness about zoonoses due to *Toxocara* species of dogs and cats in the USA found that individuals with pets and without pets were unaware of the zoonotic potential of these worm species [24]. Although, these studies focused on pet ownership and awareness about pet-borne zoonoses, research on the effect of duration of pet ownership on the perception, awareness and actions of pet owners towards animal health is majorly lacking.

4.2. Personal beliefs, health motivation factors, and actions

Our findings demonstrate that owners cues to action in relation to their dogs' GI parasitism were associated with perceived severity as well as benefits-barriers, the number of visits to the veterinarian and the availability of pet insurance. It indicated that the perceived severity increased the likelihood of dog owners performing health-related actions, including worm treatments and proper disposal of dog faeces. Also, perceived benefits showed a strong positive correlation with likelihood of worm treatments, but negative correlations with cooking meat before feeding dogs. The model also revealed that frequency of veterinary clinic visitation was a key driver of the likelihood of pet owner performing parasite control related practices.

Importantly our findings demonstrate that dog owners who have high level of perceived threats are more likely to use anthelmintic on their dogs and adequately dispose dog wastes. These results are consistent with the findings of two HBM applications looking into the likelihood of providing rabies vaccination to dogs and performing other preventive measures in Iran and Ethiopia [25,26]. In addition, our results suggest that the difference between perceived benefits and barriers seemed to have a positive impact on the likelihood of dog owners providing worm treatment to dogs and disposing dog faeces appropriately. This finding is expected since previous HBM studies have shown that both perceived benefits and barriers were strong predictors for the likelihood of performing health-related actions [27,28]. In addition, our study found that almost all respondents used anthelmintic products on their dogs, which is consistent with Palmer et al. 2008 [7]. This might indicate that most owners trust the efficacy of the antiparasitic drugs, which outweighs any potential drawbacks such as price or perceived negative side effects, and hence overcomes the perceived barriers of preventive anthelminthic treatment. Similarly, the two HBM studies on rabies preventions in Iran and Ethiopia show that those who scored higher in perceived benefits were more likely to provide vaccination to their dogs and other preventive measures [25,26]. In contrast, those who scored high in perceived barriers are less likely to perform said actions.

Our analysis indicated that there was a negative correlation between perceived benefits and feeding cooked meat to dogs. These results are unexpected as perceived benefits have been consistently found to have a strong positive influence on the likelihood of performing health-related actions [27]. However, in our study all statements that assessed perceived benefits and barriers from the HBM questions were only related to worm treatment (see Table 1). Therefore, the results of this study might not reflect the true impact of the perceived benefits on the likelihood of feeding cooked meat. Perhaps, this might also indicate that overreliance on the use of anthelmintics reduces concerns of the negative impact of the raw meat diet or the lack of awareness of the risks associated with providing raw meat in the context of gastrointestinal parasitic infection. In fact, a similar association has been reported in various studies on antiretroviral treatment of human immunodeficiency viruses (HIV), which showed the chance of performing risky behaviours, such as having unprotected sex or having multiple sexual partners, have been associated with the use of antiretroviral treatment [29–31]. Furthermore, our study found that almost 65.4% of respondents fed uncooked meat to their dogs, although the frequency was not assessed. This finding is significantly higher than the results from a study looking into the diet of dogs and cats in Australia and the USA (23.4%) [32]. These findings are quite concerning, considering the fact that raw meat could potentially contain various zoonotic parasites and other pathogens [33]. One reason behind feeding raw meat or offal to dogs is the perceived benefits of feeding raw meat to their dogs among dog owners [34]. This might possibly outweigh the perceived potential threats of parasitic infection. In fact, a recent study on the perception of owners towards raw meat-based diet showed that 94% of the respondents believed that raw meat diets were safe [34].

Our study also indicated that the frequency of veterinary visits is an important motivation factor for dog owners to perform health-related actions on their dogs and increased frequency of visitation increased the likelihood of such actions. The results indicated that visiting a veterinarian at regular intervals annually raised the likelihood of owners providing worm treatments to their dogs, feeding cooked meat to their dogs, and disposing dog faeces appropriately. This signifies that veterinarians are key influencers for improving owner perceptions on parasite control and can play a pivotal role in promoting awareness about pet-borne zoonoses in the community. Indeed, studies from the USA, Australia, and Canada have found that veterinarians are the main source of information in regard to pet health care and zoonoses [23,35,36]. While this highlights the role of veterinarians towards owner education with regards to zoonoses, unfortunately a number of remote communities in Australia do not have access to proper veterinary care and their awareness about companion animal parasitic diseases maybe compromised. This could partly explain reports of high number of free-roaming dogs and a high prevalence of parasites in dogs and soil in Indigenous communities in Australia [37,38]. Thus there is an urgent need for improvement of rural and remote veterinary facilities, education and regular training of veterinarians and support staff in spreading awareness and guidance to pet owners about dog associated parasitic zoonoses.

5. Conclusion

Our study indicates that perceptions of pet owners towards zoonotic canine parasites varies demographically and owner education is important to prevent infection among dogs and control the zoonotic transmission to owners and the community. The study also implicated that veterinarians play an important role in providing basic knowledge of canine parasites and zoonoses to their clients and influence their decisions. The current study has generated a modified-HBM which enables the assessment the perceptions, attitudes, and actions of pet owners towards pet health in a number of contexts.

Authors' contributions

TN ran the survey, collected data and undertook statistical analysis. SA was study investigator, coordinated and supervised the data collection. NC supervised the statistical analysis. RSM and NC assisted in the design and management of the study and interpretation of data. MJ, AH and JM critically reviewed the manuscript; all authors reviewed and approved the final manuscript.

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Ethics approval and consent to participate

This work was carried out with the approval of the University of Queensland Science, Low & Negligible Risk Ethics Sub-Committee; Approval Number: 2019000065.

Authors' statement

All the authors of this manuscript have contributed towards the study and write up and review of this article.

Tu Nguyen ran the survey, collected data and undertook statistical analysis and drafted the manuscript. Swaid Abdullah was study investigator, coordinated and supervised the data collection and drafting of the manuscript. Nicholas Clark supervised the statistical analysis. Ricardo J. Soares Magalhaes and Nicholas Clark assisted in the design and management of the study and interpretation of data. Malcolm K. Jones, Aaron Herndon and John Mallyon critically reviewed the manuscript; all authors reviewed and approved the final manuscript.

Declaration of Competing Interest

None of the authors of this publications have any competing interests.

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