ORIGINAL ARTICLE

Prioritizing Zoonotic Diseases: Differences in Perspectives Between Human and Animal Health Professionals in North America

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Impacts

- A quantitative approach for the prioritization of zoonotic diseases in North America by human and animal health professionals is presented.
- Human-related disease criteria were more influential for human health professionals in the decision to prioritize, while animal-related criteria were more influential for animal health professionals resulting in different disease priority lists; however, differences in preferences could be incorporated into collective decision-making by combining approaches.
- This scientific framework for disease prioritization can be used to regularly revise the disease priority list to reflect changes in diseases as they evolve over time, allowing diseases of highest threat to be identified routinely.

Keywords:
Disease prioritization; conjoint analysis; zoonotic diseases; public health; North America

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Summary

Zoonoses pose a significant burden of illness in North America. Zoonoses represent an additional threat to public health because the natural reservoirs are often animals, particularly wildlife, thus eluding control efforts such as quarantine, vaccination and social distancing. As there are limited resources available, it is necessary to prioritize diseases in order to allocate resources to those posing the greatest public health threat. Many studies have attempted to prioritize zoonoses, but challenges exist. This study uses a quantitative approach, conjoint analysis (CA), to overcome some limitations of traditional disease prioritization exercises. We used CA to conduct a zoonoses prioritization study involving a range of human and animal health professionals across North America; these included epidemiologists, public health practitioners, research scientists, physicians, veterinarians, laboratory technicians and nurses. A total of 699 human health professionals (HHP) and 585 animal health professionals (AHP) participated in this study. We used CA to prioritize 62 zoonotic diseases using 21 criteria. Our findings suggest CA can be used to produce reasonable criteria scores for disease prioritization. The fitted models were satisfactory for both groups with a slightly better fit for AHP compared to HHP (84.4% certainty fit versus 83.6%). Human-related criteria were more influential for HHP in their decision to prioritize zoonoses, while animal-related criteria were more influential for AHP resulting in different disease priority lists. While the differences were not statistically significant, a difference of one or two ranks could be considered important for some individuals. A potential solution to address the varying opinions is discussed. The scientific framework for disease prioritization presented can be revised on a regular basis by updating disease criteria to reflect diseases as they evolve over time; such a framework is of value allowing diseases of highest impact to be identified routinely for resource allocation.

Introduction

Zoonotic diseases cause a considerable burden of illness in humans (Taylor et al., 2001; Woolhouse and Gowtage-Sequeria, 2005). Past zoonotic outbreaks of significant impact in North America include West Nile virus, SARS, H1N1 influenza and Lyme disease (Borgundvaag et al., 2004; Bacon et al., 2008; Kermode-Scott, 2009; Lindsey et al., 2010). The current Ebola virus outbreak in West Africa is an example of how diseases of zoonotic origin can pose an international threat requiring immediate response in affected countries and emergency preparedness in unaffected countries (Centers for Disease Control and Prevention, 2014; Public Health Agency of Canada, 2014; World Health Organization, 2014). For response efforts to occur in a timely manner, diseases should already be identified as high priority with preventative measures in place at the regional and national level. Zoonotic diseases pose an additional threat because the natural reservoirs are often animals, particularly wildlife, thus eluding control efforts such as quarantine, vaccination and social distancing. With limited resources available, it is necessary to prioritize diseases in order to allocate resources to those posing the greatest public health threat. Many studies have attempted to prioritize communicable diseases (Rushdy and O'Mahony, 1998; Doherty, 2000, 2006; Horby et al., 2001; World Health Organization, 2003; Krause et al., 2008a; Balabanova et al., 2011; Cox et al., 2013), zoonotic diseases (Institut de Veille Sanitaire, 2002, 2010; Cardoen et al., 2009; Havelaar et al., 2010; Humblet et al., 2012) and animal diseases (Del Rio Vilas et al., 2013; Brookes et al., 2014a,b). Numerous challenges have been identified; these include the difficulty in comparing multiple diseases that vary greatly in health outcomes and socio-economic impact in humans and animals (Pan American Health Organization, 2003; Heymann, 2008); the multiple stakeholders involved who have their own objectives and opinions; and the various prioritization methodologies that have been developed to date but a lack of agreement on best practices (Krause et al., 2008a,b; Gilsdorf and Krause, 2011). One of the main technical challenges for the lack of agreement on which prioritization method to use has been the process of deriving scores and weights to mathematically quantify the disease criteria used to evaluate diseases. Earlier studies used simplified linear scores applied to disease criteria separately (Rushdy and O'Mahony, 1998; Doherty, 2000, 2006; Horby et al., 2001; World Health Organization, 2003) or experts to derive subjective weights that are then applied to disease criteria separately (Krause et al., 2008a,b; Cardoen et al., 2009; Balabanova et al., 2011; Humblet et al., 2012; Cox et al., 2013). These simplified approaches introduce subjective bias into the prioritization exercise and make the assumption that disease criteria are independent, which they are not. Recent studies have utilized various quantitative approaches to address these limitations (Havelaar et al., 2010; Del Rio Vilas et al., 2013; Brookes et al., 2014a,b).

Our study used a quantitative approach, conjoint analysis (CA), to overcome these limitations. CA is a technique developed for market research to explore consumer preferences (Green and Srinivasan, 1978). However, CA has been gaining widespread use over the last decade for eliciting preferences in the healthcare setting (Ryan and Farrar, 2000; Mele, 2008; Sampietro-Colom et al., 2008; Bridges et al., 2011). The theory behind CA is that a product can be described by a set of characteristics and that the extent to which an individual values a product is determined by the level of each characteristic and the combination of those levels of characteristics together (Ryan and Farrar, 2000; Mele, 2008; Orme, 2010). A CA study presents individuals with multiple competing products, each containing desirable and undesirable characteristics and forces the individual to state a preference, usually by selecting one product over the others. In doing so, the value of each characteristic, relative to each other, is revealed through the choice data. We used CA for the prioritization of zoonoses by treating diseases as products and describing each disease as a set of disease criteria (characteristics) (Ng and Sargeant, 2012a, 2013). Because relative weighted scores for each disease criterion and their corresponding levels were derived from the choice data, we overcome the problem of subjective bias in disease criteria scores and weights and acknowledged that characteristics are not independent. Additional benefits for using CA included presenting individuals with a set of disease criteria without identifying diseases, thus eliminating biases associated with disease names and forcing individuals to prioritize solely on scientific knowledge. Further, because individuals are presented with all the information about the diseases to consider for prioritization, CA allows for widespread participation rather than a limited group of experts (Ng and Sargeant, 2012a, 2013).

We previously published results from our zoonoses prioritization study from the general public (Ng and Sargeant, 2012a) and health professionals as a complete group (Ng and Sargeant, 2013). The primary objective of this study was to separate the human health professionals (HHP) from the animal health professionals (AHP) and present the differences in zoonoses prioritization between these two distinct groups. The secondary objective was to discuss the implications for disease prioritization in the face of multiple stakeholders with competing objectives and opinions.

Materials and Methods

Study participants

Our target participants represented a range of human and AHP including epidemiologists, public health practitioners

In your opinion, which of the following diseases should be prioritized for policy implementation for their control and prevention in Canada/US*, assuming all other characteristics not presented here are the same between diseases:

Disease criteria	Zoonoses 1	Zoonoses 2	Zoonoses 3	Zoonoses 4	Zoonoses 5
Transmission potential from animals to humans	Moderate	Low	High	High	Moderate
Transmission potential between humans	Low	Moderate	High	No transmission between humans	No transmission between humans
Severity of illness in humans	Mild clinical symptoms	No clinical symptoms or illness that is not noticeable	Moderate clinical symptoms	Moderate clinical symptoms	Severe clinical symptoms
Duration of illness in animals	Medium-term illness (months)	Chronic illness or illness with permanent deficits	No illness observed or only a few days of illness	Short-term illness (weeks)	Medium-term illness (months)
High-risk groups in humans	No	No	Yes	Yes	Unknown
	○	○	○	○	○

Fig. 1. Example of one choice task set completed by each study participant. As multiple survey versions were administered randomly to each person, a different combination of disease criteria and levels was presented to study participants. The ordering of the presentation of disease criteria within each choice task was randomized to reduce ordering bias.

and policymakers at the local, provincial/state and national level, academic and practicing physicians and veterinarians, infectious disease researchers, human and animal health laboratory microbiologists, pathologists and technicians, and registered nurses. Participants from Canada and the United States were invited to participate through email invitation and in-person recruitment using the methods previously described (Ng and Sargeant, 2013). Online surveys were completed between November 2010 and January 2012. Sample size calculations were estimated using Sawtooth Software SSI Web v7 (Sawtooth Software, 2012a); a minimum of 500 study participants per professional group was needed for model fitting.

Survey development and instrument

The methods for criteria identification, disease selection, literature review, defining levels for disease criteria, survey development and administration have been described previously (Ng and Sargeant, 2012a, 2013). To summarize, six focus groups identified 21 criteria for disease prioritization (Ng and Sargeant, 2012b), and 62 zoonotic and enteric diseases were selected on the basis of their public health importance (Ng and Sargeant, 2012a). Diseases were further divided into separate syndromes, for example acute/chronic phases and latent/active phases; 117 separate disease syndromes were identified from the 62 diseases, and proportions for each syndrome within a given disease were assigned according to the literature. For each criterion for each disease syndrome, a literature search was conducted comprising reference textbooks, peer-reviewed publications and websites (Ng and Sargeant, 2012a). Criterion levels were then defined according to the range reported in the literature with three or four levels assigned to each criterion. A partial-profile choice-based conjoint (CBC) study was developed comprising 14 choice task sets (Patterson and Chrzan, 2003; Chrazn, 2010); each choice task contained five disease scenarios and each scenario contained five disease criteria (Fig. 1). Disease criteria were rotated throughout the survey using an orthogonal experiment design, and criteria and levels were varied between choice tasks. The ordering of disease criteria within a choice task was randomized. In addition, two fixed choice tasks were included to test the reliability of responses; these choice tasks were designed to identify respondents who did not understand the choice task process or fatigued responders.[1] Fixed choice tasks were also randomized to reduce ordering bias. For each choice task, respondents were asked to select one disease to prioritize for their control and prevention in Canada or the United States. A total of 300 survey versions containing 14 choice task sets and two fixed choice task sets were created using Sawtooth Software CBC module v7

[1]Fixed choice task 1 presented one zoonosis with the highest incidence in humans (10 000 cases), most severe illness in humans (severe clinical symptoms), highest transmission potential between humans (high), highest case fatality in humans (80%) and the most costly economic burden in humans ($10 000 per sick individual). In comparison, the remaining four zoonoses contained a combination of lower and less severe criteria levels.

Fixed choice task 2 presented one zoonosis with the most severe illness in animals (severe clinical symptoms), highest case fatality in animals (80%), most costly socio-economic burden in trade in animals (high cost such as culling of herds or destroying infected crops/produce), longest duration of illness in animals (chronic illness or permanent deficits) and rapid change in disease trend in the human population (new emerging disease, rapid increase over the last 5 years). In comparison, the remaining four zoonoses contained a combination of lower and less severe criteria levels.

(Sawtooth Software, 2012b), each version contained an efficient experimental design utilizing a balance overlap approach (Sawtooth Software, 2008). Sawtooth Software SSI Web v7 was used to randomly assign survey version to study participants (Sawtooth Software, 2012a). Participants could choose to complete the survey in English, French or Spanish.

Data analysis

Individual-level parameter estimates (weighted scores) for each disease criterion level were derived from the survey choice data using Sawtooth Software CBC/HB v5.2.8 (Sawtooth Software, 2012c). The program utilizes hierarchical Bayes (HB) theorem combining a Markov chain Monte Carlo procedure with the Metropolis/Hasting algorithm to iteratively update the parameter estimates from an upper-level prior model to a lower-level posterior model (Sawtooth Software, 2009). The prior model represents the study population; the HB algorithm estimates the average parameters for the population before using respondent's individual-level data to determine how each respondent differs from the population mean. The algorithm adjusts each respondent's parameter estimates (posterior model) so that they reflect an optimal mix of the population mean and the individual's choices. The optimal model is dependent on the quality of data provided by each respondent (posterior) and the variance in the population mean (prior); the greater the population variance, the less Bayesian correction is applied to the mean so that individuals are allowed to vary in their choices and their parameter estimates provide better fit to their individual-level responses (Howell, 2009). A total of 30 000 preliminary iterations were computed for model convergence, and an additional 30 000 iterations were computed for parameter estimation. Percentage certainty and root likelihood (RLH) goodness-of-fit measures were calculated to determine how well the final model fit was in comparison with a chance model and a perfect model. A chance model has a percentage certainty fit of 0%, and a perfect model has a percentage certainty fit of 100% (Sawtooth Software, 2009). The expected RLH for a chance model is determined by how many scenarios are presented per choice task set; the RLH for a chance model in this study was 0.2 (one divided by five disease scenarios per task), and the expected RLH for a perfect model was 1. (Sawtooth Software, 2009). The final parameter estimates, referred to as part-worth utilities (β), for each criterion level were converted to zero-centred standardized utility values by setting the average range of parameter values across all disease criteria to 100.

The part-worth utilities, β, represent the influence each criterion level had on the respondent choices; the further the part-worth utilities deviate from zero, the stronger the influence the level had on choice (Orme, 2010). Scores for each disease syndrome were calculated as the summation of part-worth utilities matching criterion levels that were assigned to the corresponding disease syndrome. Scores were then summed up in proportion to the frequency of each syndrome within a disease to derive an overall score for each disease. The overall scores were used to rank diseases from highest priority (highest score) to lowest priority (lowest score). Because part-worth utilities represent interval data, overall scores cannot be compared between groups; instead, disease ranks were compared as a measure of proximal agreement or disagreement in prioritization between groups. Importance scores can be derived from part-worth utilities to estimate the influence the combined levels for each disease criterion had on the decision to prioritize. Importance scores are calculated as a percentage for each respondent; for each disease criterion, the difference in range between the highest and lowest part-worth utility is divided by the sum of all part-worth utility ranges across all 21 disease criteria. The larger the difference between the levels within a criterion, the higher the importance score and thus, the stronger the influence the criterion had on the decision to prioritize (Orme, 2010).

Chi-squared and Fisher's exact tests were used to compare demographic and professional background characteristics of study participants. Unpaired *t*-tests, *F*-tests and Welch's *t*-tests were used to explore differences in importance scores between human and AHP. Spearman's rank correlation was used to compare disease priority ranks between the professionals.

Results

Survey and demographic characteristics

A total of 707 Canadian and 764 US professionals from a wide range of demographic and professional backgrounds completed and passed the survey (Tables 1 and 2). Participants passed the survey if they provided responses for all 14 choice tasks and correctly responded to the fixed choice tasks. Response rates could not be calculated due to the recruitment methodology (Ng and Sargeant, 2013). Amongst the Canadian professionals, 328 (46.4%) self-identified as HHP, 304 (43.0%) as AHP and 75 (10.6%) as both human and AHP. Amongst the US professionals, 371 (48.6%) self-identified as HHP, 281 (36.8%) as AHP and 112 (14.6%) as both. There were 699 HHP surveys and 585 AHP surveys available for analysis. The combined HHP and AHP group was excluded from analysis due to small numbers ($n = 187$). The median completion time for HHP was 25.0 and 29.4 min for AHP ($n = 585$); there was a significant difference in the completion time between professional groups ($P < 0.001$). Although the survey was offered in three languages (English and French in Canada and

Table 1. Demographic characteristics of animal and human health professionals by country

	Canada (n = 632)				United States (n = 652)			Canada and United States (n = 1284)		
	Human health professionals (n = 328) (%)	Animal health professionals (n = 304) (%)	χ^2		Human health professionals (n = 371) (%)	Animal health professionals (n = 281) (%)	χ^2	Human health professionals (n = 699) (%)	Animal health professionals (n = 585) (%)	χ^2
Gender										
Male	45.1	44.4	0.04		34.2	42.0	4.5	39.3	43.3	6.9*
Female	54.3	54.9			65.0	57.7		59.9	56.2	
Unknown	0.6	0.7			0.8	0.4		0.7	0.5	
Age group										
18 to 34	24.7	28.6	3.6		28.3	18.2	13.7*	26.6	23.6	2.0
35 to 50	36.0	29.3			33.2	31.0		34.5	30.1	
50+	38.4	41.5			37.7	50.5		38.1	45.8	
Unknown	0.9	0.7			0.8	0.4		0.9	0.5	
Province				Region						
Alberta	8.2	13.8	40.5*	Midwest	18.6	28.1	10.2*	–		
British Columbia	8.5	8.2		Northeast	19.7	13.5				
Manitoba	6.4	5.9		South	34.8	33.1				
New Brunswick	0.9	2.3		West	27.0	25.3				
Newfoundland and Labrador	2.4	2.0								
Nova Scotia	4.3	2.0								
Northwest Territories	0.6	0.0								
Nunavut	0.0	0.0								
Ontario	52.4	43.1								
Prince Edward Island	0.3	3.3								
Quebec	13.4	9.2								
Saskatchewan	2.4	9.2								
Yukon	0.0	0.3								
Unknown	0.0	0.7								
Education attainment										
High school graduate or less	0.6	0.3	44.6*		5.1	2.5	137.6*	3.0	1.4	48.7*
Diploma, trade or college degree	2.8	4.6			1.1	0.0		1.9	2.4	
Bachelor's degree	18.4	8.2			21.1	6.0		19.8	7.2	
Master's degree	19.0	6.6			30.5	5.7		25.1	6.2	
Professional degree (MD, DVM)	42.9	57.9			24.3	60.5		33.1	59.2	
Doctorate degree	16.3	22.4			17.8	25.3		17.1	23.8	

MD – Doctor of Medicine degree, DVM – Doctor of Veterinary Medicine degree.

Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin); *Northeast* (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont); *South* (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia); *West* (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming).

*Significant at $P < 0.05$.

Table 2. Professional background characteristics of human and animal health professionals by country.

	Canada (n = 632)			United States (n = 652)			Canada and United States (n = 1,284)		
	Human health professionals (n = 328) (%)	Animal health professionals (n = 304) (%)	χ^2	Human health professionals (n = 371) (%)	Animal health professionals (n = 281) (%)	χ^2	Human health professionals (n = 699) (%)	Animal health professionals (n = 585) (%)	χ^2
Professional disciplines									
Epidemiology	11.6	5.9	439.6*	19.1	10.0	428.2*	15.6	7.9	868.1*
Public Health	25.9	2.3		31.8	3.2		29.0	2.7	
Physician or Medical Sciences	41.5	0.7		19.7	0.0		29.9	0.3	
Infectious Disease Research	5.5	4.0		8.1	5.3		6.9	4.6	
Human Disease Laboratory Technician	0.6	0.0		3.0	0.0		1.9	0.0	
Veterinarians and Veterinary Sciences	0.6	72.0		0.0	67.3		0.3	69.7	
Animal Health Laboratory Technician	0.3	3.0		0.0	1.8		0.1	2.4	
Nursing	4.9	0.3		8.9	0.0		7.0	0.2	
Other Profession[a]	9.2	11.8		8.4	12.5		8.7	12.1	
Unknown[b]	0.0	0.0		1.1	0.0		0.6	0.0	
Years in employment									
Less than 1 year	3.1	2.6	6.1	4.6	2.5	30.6*	3.9	2.6	26.0*
>1–3 years	10.1	6.6		12.7	4.6		11.4	5.6	
>3–5 years	11.3	8.2		11.3	7.1		11.3	7.7	
>5–10 years	14.6	17.4		16.2	10.3		15.5	14.0	
>10 years	60.7	65.1		55.0	74.7		57.7	69.7	
Unknown	0.3	0.0		0.3	0.7		0.3	0.3	
Workplace of employment									
Academia	33.2	20.1	42.4*	28.3	31.7	12.7*	30.6	25.6	29.3*
Government	42.7	40.8		43.7	31.0		43.2	36.1	
Industry	2.4	14.1		9.4	11.0		6.2	12.7	
Hospital/Clinic	13.1	19.1		9.7	10.3		11.3	17.1	
Other[c]	7.6	5.6		8.4	15.0		8.0	7.9	
Unknown	0.9	0.3		0.5	1.1		0.7	0.7	

*Significant at $P < 0.05$.

[a]Includes other medical and science-related disciplines such as health education, travel medicine, wildlife and aquatic biologists, environmental and ecosystem health, occupational and environmental health and safety, medical entomologists, food inspection and risk assessment, regulatory medicine and policy.

[b]This group consisted of four individuals who selected the 'I prefer not to answer' response for professional discipline but who identified themselves as either animal health or human health professionals with at least one year of work experience and working in academia, industry or a hospital/clinic.

[c]Includes non-government organizations, private consultancy, small businesses, aquariums and zoos, farms, and medical and veterinary associations.

English and Spanish in the United States), all US surveys were completed in English. There was no significant difference in the pass rate between Canadian surveys completed in English (n = 676/884) and in French (n = 31/44) (P = 0.361).

Demographic differences were observed between HHP and AHP, both within and between countries (Table 1). A significantly higher proportion of AHP in Canada were from Alberta (13.8% versus 8.2%), Prince Edward Island (3.3% versus 0.3%) and Saskatchewan (9.2% versus 2.4%), likely due to the presence of veterinary colleges in these provinces and thus an indication of the distribution of AHP across Canada. A significantly higher proportion of HHP in Canada were from Ontario (52.4% versus 43.1%) and Quebec (13.4% versus 9.2%), similarly likely due to the presence of multiple medical

schools in these provinces and the corresponding job market. Similar trends were observed in the United States. Human health professionals were more likely to hold a Bachelor's degree (19.8% versus 7.2%) or Master's degree (25.1% versus 6.2%), while AHP were more likely to hold a professional degree (59.2% versus 33.1%) or doctorate degree (23.8% versus 17.1%). This may represent the various paths through which HHP enter their professions compared to AHP. The majority of AHP in both countries were veterinarians or working in veterinary sciences (69.7%) or as epidemiologists (7.9%), but HHP represented a mix of disciplines including physicians or medical sciences (29.9%), public health practitioners (29.0%), epidemiologists (15.6%), nurses (7.0%) and infectious disease researchers (6.9%). Despite differences in demographic and professional backgrounds, the study populations reflect a broad representation of HHP and AHP in North America. As our previous study described the differences between Canadian and US professionals (Ng and Sargeant, 2013), this study will focus on the differences between combined HHP and combined AHP in North America.

Model fit

The HHP model had a percentage certainty fit of 83.6% and a RLH of 0.77; the AHP model had a percentage certainty fit of 84.8% and a RLH of 0.78. Although the models presented in this study do not represent perfect models, they produced satisfactory percentage certainty fit and RLH values indicating that the part-worth utilities derived from the models are acceptable.

Disease criteria importance scores and part-worth utilities

Importance scores for disease criteria represent the proportion each criterion contributed to the overall decision to prioritize. For HHP, human-related criteria contributed more to the decision to prioritize over corresponding animal-related criteria for each of the eight matching criteria (Table 3 and Fig. 2). The four transmission potential criteria contributed in the following order: animal-to-human, human-to-human, animal-to-animal and human-to-animal, also indicating a stronger preference for human-related criteria. In contrast, AHP considered six of the eight matching criteria to be more important in humans than in animals, but two animal-related criteria were considered more important: economic and social burden in animals and efficacy of control measures in animals. The importance score ordering for the four transmission potential criteria was identical to the HHP group.

The HHP group considered disease incidence in humans to be the most important criterion. There were nine criteria with significantly higher importance scores in the HHP group compared to the AHP group ($P < 0.0024$ for all, Table 3), of these seven were human-related criteria (disease incidence, case fatality, disease trend, duration of illness, human-to-human transmission potential, control measures and high-risk groups). The remaining two were animal-related criteria (duration of illness and high-risk groups) but reflect criteria with lower importance scores. Although AHP considered case fatality in humans to be the most important criterion, they also considered some animal-related criteria to be of higher importance than their human counterpart. These were economic and social burden in animals, disease trend in animals, animal-to-animal transmission potential and severity of illness in animals ($P < 0.0024$ for all, Table 3). The disease criteria with the largest *t*-statistic difference between HHP and AHP for which HHP placed higher importance on were high-risk groups in humans, disease incidence in humans, human-to-human transmission and control measures in humans (all are human-related criteria). Conversely, the disease criteria for which AHP placed higher importance on were socio-economic burden in animals, animal-to-human transmission, severity of illness in animals and animal-to-animal transmission (three of four are animal-related criteria).

The part-worth utilities represent the weight each level within each disease criterion contributed to the overall decision to prioritize (Table 4). The further the part-worth utilities deviated from zero, the stronger the influence of the level. The wider the range in part-worth utilities between the highest and lowest levels within a criterion, the more influence that criterion had on the decision to prioritize. Significant differences were observed for the majority of part-worth utilities between the HHP and AHP (65 of 82 criterion levels); this is due to the difference in preferences with HHP placing higher preference on human-related criteria and AHP placing higher preference on animal-related criteria. The effect of this difference is observed in the derived disease priority lists (Table 5).

Disease priority lists

Both groups considered rabies to be the most important zoonoses to prioritize while Dengue fever, La Crosse encephalitis and St. Louis encephalitis were the least important (Table 5). While there were differences in the ranking of the majority of other diseases between the two groups, the mean difference across all diseases was three ranked positions indicating no statistical difference between groups (Spearman's rho = 0.9759, $P < 0.001$). The list of diseases includes a broad group of zoonotic diseases, many of which may not be relevant for all stakeholder groups. The priority list could therefore be analysed by subgroups of diseases

Table 3. Disease criteria importance scores by human and animal health professionals by country

	Canada and United States (n = 1284)				
	Human health professionals (n = 699)		Animal health professionals (n = 585)		Human versus animal health professionals t-statistic
Disease criteria[a]	Rank[b]	Mean score[c]	Rank[b]	Mean score[c]	
Disease incidence (H)	1	**9.45**	2	7.99	14.3*
Case fatality (H)	2	**8.68**	1	8.12	5.6*
Disease trend (H)	3	**7.23**	3	6.97	3.2*,[d]
Disease incidence (A)	4	6.69	5	6.73	−0.6[d]
Severity of illness (H)	5	6.55	4	6.76	−2.3[d]
Economic burden (H)	6	6.02	7	6.10	−0.9[d]
Duration of illness (H)	7	**5.38**	11	5.03	4.2*,[d]
Disease trend (A)	8	5.23	9	**5.87**	−7.2*,[d]
Case fatality (A)	9	5.05	10	5.17	−1.7
Transmission potential (A-H)	10	5.04	8	**5.88**	−12.0*
Transmission potential (H-H)	11	**5.03**	12	4.12	13.1*,[d]
Economic and social burden (A)	12	4.07	6	**6.41**	−30.4*,[d]
Control measures (H)	13	**3.92**	17	3.04	9.0*,[d]
Transmission potential (A-A)	14	3.36	13	**3.85**	−9.0*,[d]
Control measures (A)	15	3.30	14	3.53	−2.3[d]
Transmission potential (H-A)	16	3.22	16	3.07	2.4[d]
Duration of illness (A)	17	**2.70**	18	2.52	3.4*
Severity of illness (A)	18	2.69	15	**3.26**	−10.5*
High-risk groups (H)	19	**2.47**	20	1.81	14.7*,[d]
Scientific information	20	2.45	19	2.49	−0.5[d]
High-risk groups (A)	21	**1.49**	21	1.28	5.0*

Scores in bold indicate disease criteria with statistically significant difference in importance scores between respective comparison groups; scores for the country with the highest score (i.e. placed more importance on) are in bold.

*Significant at $P < 0.0024$; Bonferroni-corrected P-value cut-off.

[a]Disease criteria (H) = human-related characteristic, for example disease incidence in *humans*; disease criteria (A) = animal-related characteristic, for example disease incidence in *animals*. For the four transmission potential criteria, A-H = animal-to-human transmission, H-H = human-to-human transmission, A-A = animal-to-animal transmission and H-A = human-to-animal transmission.

[b]Relative rank of disease criteria by importance scores for the corresponding group of respondents; table is presented in order of importance for human health professionals.

[c]Mean importance score across respondents.

[d]Adjusted for unequal variance (identified by the F-test of equality of variances) using the Welch t-test.

with common characteristics, for example vectorborne diseases, foodborne and enteric diseases, exotic diseases, endemic diseases or diseases of specific commodity groups. The priority diseases by subgroups were vectorborne diseases (leishmaniasis, Chagas' disease and the plague for HHP; leishmaniasis, Crimean-Congo haemorrhagic fever and Chagas' disease for AHP), foodborne and enteric diseases (listeriosis, variant Creutzfeldt–Jakob disease and cryptosporidiosis for HHP; variant Creutzfeldt–Jakob disease, listeriosis and botulism for AHP), exotic diseases (Nipah virus encephalitis, Ebola virus haemorrhagic fever and Marburg haemorrhagic fever for both HHP and AHP) and endemic diseases (rabies, H1N1 influenza and listeriosis for HHP; rabies, variant Creutzfeldt–Jakob disease and H1N1 influenza for AHP). Although differences were also observed by subgroups, the differences were not statistically significant ($P < 0.001$ for all subgroups). Generally, diseases of high priority were characterized by high disease incidence (H/A), high case fatality (H), increasing or emerging disease trend (H/A), high severity of illness (H), high socio-economic burden (H/A) and high transmission potential from animals to humans, but it was not necessary to have each of these characteristics to be identified as a high priority disease (e.g. rabies incidence in humans and animals is low, and disease trend has been stable over the last 5 years).

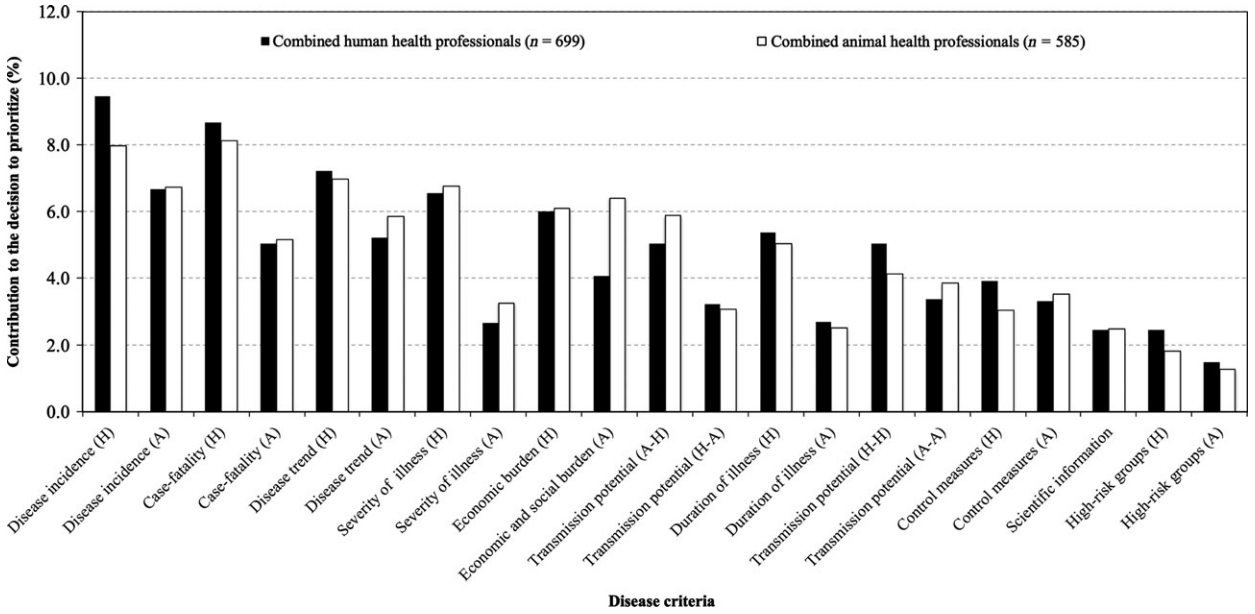

Fig. 2. Mean disease criteria importance scores by human and animal health professional groups. Disease criteria are presented in order of the human-related criteria with the highest mean score across both groups, followed by the corresponding animal-related criteria.

Discussion

Zoonotic diseases pose a significant burden of illness in North America (Borgundvaag et al., 2004; Bacon et al., 2008; Kermode-Scott, 2009; Lindsey et al., 2010). Even diseases that are not endemic to North America pose a threat to the population due to international travel (Centers for Disease Control and Prevention, 2014; Public Health Agency of Canada, 2014; World Health Organization, 2014). We previously presented on the use of CA for the prioritization of zoonoses in North America by the general public (Ng and Sargeant, 2012a) and aggregated professional groups (Ng and Sargeant, 2013). Here, we present the results of the professional groups separated by HHP and AHP to explore differences in disease prioritization between these groups. We selected CA to fit statistical models to choice data within a mathematical framework, thus generating relative weighted scores for disease criteria and levels; this allowed us to overcome the limitation of assigning arbitrary linear scores and subjective weights to disease criteria and levels. The use of CA also allowed for disease criteria and levels to be considered jointly, thus the derived weighted scores account for interactions between criteria and levels. There has been a shift towards the use of statistical and mathematical methods similar to CA to elicit and reveal weighted scores from individuals rather than to explicitly solicit scores and weights for disease criteria and levels (Havelaar et al., 2010; Brookes et al., 2014a,b). However, as the prioritization objectives, study participants, and the diseases being prioritized differ between studies, it is not feasible to compare methods objectively.

Model fits were satisfactory for both groups. The disease criteria scores derived were rational and consistent with other studies presenting similar criteria (Rushdy and O'Mahony, 1998; Doherty, 2000, 2006; Horby et al., 2001; Institut de Veille Sanitaire, 2002, 2010; World Health Organization, 2003; Krause et al., 2008a; Cardoen et al., 2009; Havelaar et al., 2010; Balabanova et al., 2011; Humblet et al., 2012; Cox et al., 2013; Del Rio Vilas et al., 2013; Brookes et al., 2014a,b). The part-worth utilities were also logical with higher preferences given to higher levels and lower preferences to lower levels. The disease priority list generated by applying part-worth utilities to the diseases and their syndromes produced a reasonable list of diseases to prioritize, particularly when diseases were categorized by subgroups.

We included a wide range of health professionals in our study: doctors and veterinarians who treat patients and animals, nurses representing the frontline of defence for patients seeking medical care, laboratory technicians who have an understanding of the identification and diagnosis of disease-causing pathogens, infectious disease researchers who have expertise on various aspects of communicable diseases, and public health practitioners and epidemiologists who understand the impact of diseases at the population level. Each profession has a unique understanding of diseases from a different perspective and can add much value to the decision to prioritize zoonoses, yet many disease prioritization studies are often limited to disease

Table 4. Disease criteria and standardized part-worth utilities for human health and animal health professionals

Disease criteria[a] and corresponding levels	Human health professionals (n = 699)			Animal health professionals (n = 585)			
	β[b]	LCL[c]	UCL[d]	β[b]	LCL[c]	UCL[d]	t[e]
Incidence of the disease in the Canadian/US human population in the last 5 years							
0 cases	−93.99	−95.37	−92.61	−75.77	−77.21	−74.33	−17.81***
5 cases	−33.96	−35.38	−32.54	−38.92	−39.91	−37.93	5.60***,[f]
100 cases	24.30	23.05	25.56	23.77	22.71	24.83	0.64[f]
10 000 cases	103.65	101.74	105.56	90.92	88.90	92.94	8.93***
Case fatality in humans							
No deaths or deaths are rarely reported	−85.32	−86.88	−83.77	−76.80	−78.60	−75.00	−7.06***
Case fatality is low (6%)	−41.83	−43.13	−40.54	−44.55	−46.23	−42.87	2.51*,[f]
Case fatality is moderate (35%)	32.02	30.68	33.36	29.75	27.90	31.59	1.96[f]
Case fatality is high (80%)	95.13	93.37	96.90	91.60	89.92	93.29	2.83*,[f]
Disease trend in Canada/United States in the last 5 years in humans							
Decline over the last 5 years	−73.87	−75.59	−72.14	−75.77	−77.28	−74.26	1.63[f]
Stable over the last 5 years	−29.27	−30.55	−27.98	−26.06	−27.47	−24.64	−3.30**
Increase over the last 5 years	28.49	27.14	29.84	32.33	30.83	33.84	−3.73***
New emerging disease, rapid increase over the last 5 years	74.64	72.92	76.37	69.50	68.22	70.77	4.71***,[f]
Incidence of the disease in the Canadian/US animal population in the last 5 years							
0 cases	−62.80	−64.13	−61.47	−61.90	−63.19	−60.60	−0.96[f]
5 cases	−32.08	−33.17	−31.00	−32.26	−33.56	−30.96	0.21[f]
100 cases	19.56	18.50	20.61	16.52	15.61	17.42	4.29***,[f]
10 000 cases	75.33	73.69	76.97	77.64	76.12	79.17	−2.02*,[f]
Severity of illness in humans							
No clinical symptoms or illness that is not noticeable	−66.27	−67.50	−65.05	−69.86	−71.56	−68.16	3.36***,[f]
Mild clinical symptoms (time off work, some medical assistance and personal care at home)	−28.23	−29.42	−27.05	−24.28	−25.64	−22.92	−4.32***
Moderate clinical symptoms (urgent medical care and hospital admission)	24.88	23.82	25.94	23.50	22.34	24.66	1.71
Severe clinical symptoms (failure of major organ system(s) necessitating long-term hospital admission)	69.63	68.02	71.24	70.64	68.95	72.32	−0.84
Economic burden in humans							
No cost to the healthcare system and individuals	−59.81	−61.71	−57.90	−60.70	−62.30	−59.10	0.70[f]
Low cost ($100 per sick individual)	−20.49	−21.67	−19.30	−21.34	−22.50	−20.18	1.01[f]
Moderate cost ($1000 per sick individual)	20.21	19.17	21.26	16.78	15.71	17.86	4.46***
High cost ($10 000 per sick individual)	60.08	57.84	62.32	65.26	63.91	66.60	−3.88***,[f]
Duration of illness in humans							
No illness observed or only a few days of illness	−51.67	−53.21	−50.13	−46.60	−48.00	−45.20	−4.77***,[f]
Short-term illness (weeks)	−18.40	−19.55	−17.24	−15.73	−17.00	−14.46	−3.05**
Medium-term illness (months)	11.50	10.45	12.56	6.17	4.96	7.38	6.55***
Chronic illness (years) or illness with permanent deficits	58.56	56.93	60.19	56.16	54.48	57.85	1.99*
Disease trend in Canada/United States in the last 5 years in animals							
Decline over the last 5 years	−54.11	−55.39	−52.83	−59.53	−61.40	−57.67	4.70***,[f]
Stable over the last 5 years	−21.82	−22.83	−20.81	−26.91	−28.07	−25.75	6.53***
Increase over the last 5 years	23.40	22.41	24.38	27.57	26.43	28.71	−5.46***
New emerging disease, rapid increase over the last 5 years	52.53	50.92	54.14	58.87	57.15	60.60	−5.25***

Table 4. (Continued)

Disease criteria[a] and corresponding levels	Human health professionals (n = 699)			Animal health professionals (n = 585)			
	β[b]	LCL[c]	UCL[d]	β[b]	LCL[c]	UCL[d]	t[e]
Case fatality in animals							
No deaths or deaths are rarely reported	−47.57	−48.67	−46.46	−40.04	−41.22	−38.86	−9.08***
Case fatality is low (6%)	−25.51	−26.47	−24.54	−37.71	−38.82	−36.61	16.40***
Case fatality is moderate (35%)	17.32	16.23	18.42	16.40	15.10	17.71	−1.06[f]
Case fatality is high (80%)	55.75	54.43	57.07	61.35	59.78	62.93	−5.34***,[f]
Transmission potential from animals to humans							
No transmission from animals to humans	−47.32	−48.62	−46.01	−57.16	−58.60	−55.71	9.93***
Low transmission from animals to humans	−25.65	−26.85	−24.45	−31.18	−32.23	−30.14	6.82***,[f]
Moderate transmission from animals to humans	18.98	18.08	19.88	24.49	23.33	25.66	−7.34***,[f]
High	53.99	52.63	55.36	63.85	62.62	65.07	−10.51***,[f]
Transmission potential between humans							
No transmission between humans	−47.40	−48.87	−45.92	−35.22	−36.30	−34.13	−13.06***,[f]
Low transmission between humans	−28.36	−29.49	−27.24	−26.32	−27.51	−25.14	−2.43*
Moderate transmission between humans	20.59	19.46	21.72	15.21	14.04	16.38	6.46***
High transmission between humans	55.17	53.85	56.49	46.33	45.29	47.37	10.32***,[f]
Economic and social burden on trade in animals							
No cost to trade in animals	−32.78	−33.94	−31.63	−51.50	−52.99	−50.00	19.42***,[f]
Low cost to trade in animals (vaccination of herds)	−19.71	−20.76	−18.66	−41.99	−43.36	−40.62	25.25***,[f]
Moderate cost to trade in animals (restriction of movement and trade)	5.13	4.13	6.13	15.72	14.64	16.80	−14.12***
High cost to trade in animals (culling of herds or destroying infected crops/ produce)	47.36	46.02	48.70	77.77	76.06	79.47	−27.49***,[f]
Efficacy of control measures in humans							
Highly effective in reducing disease burden	13.96	10.70	17.23	−5.05	−8.23	−1.87	8.18***,[f]
Moderately effective in reducing disease burden	12.76	11.23	14.30	7.00	5.91	8.08	6.00***,[f]
Minimally effective in reducing disease burden	−8.93	−10.54	−7.31	0.43	−1.39	2.26	−7.55***
Not effective at all in reducing disease burden	−17.80	−20.73	−14.87	−2.38	−4.69	−0.06	−8.10***,[f]
Transmission potential between animals							
No transmission between animals	−26.22	−27.50	−24.94	−35.06	−36.10	−34.03	10.56***,[f]
Low transmission between animals	−21.40	−22.43	−20.36	−21.26	−22.41	−20.11	−0.17
Moderate transmission between animals	11.85	10.84	12.86	15.26	14.17	16.34	−4.49***
High transmission between animals	35.76	34.72	36.80	41.07	40.11	42.03	−7.34***,[f]
Efficacy of control measures in animals							
Highly effective in reducing disease burden	24.15	21.87	26.43	12.79	9.53	16.05	5.60***,[f]
Moderately effective in reducing disease burden	13.14	11.80	14.47	12.47	10.66	14.28	0.58[f]
Minimally effective in reducing disease burden	−14.47	−16.00	−12.93	−12.70	−15.08	−10.33	−1.22[f]
Not effective at all in reducing disease burden	−22.82	−24.91	−20.73	−12.56	−15.35	−9.77	−5.77***,[f]

Table 4. (Continued)

Disease criteria[a] and corresponding levels	Human health professionals (n = 699)			Animal health professionals (n = 585)			
	β[b]	LCL[c]	UCL[d]	β[b]	LCL[c]	UCL[d]	t[e]
Transmission potential from humans to animals							
No transmission from humans to animals	−30.43	−31.79	−29.07	−26.91	−28.26	−25.55	−3.60***,[f]
Low transmission from humans to animals	−14.37	−15.39	−13.35	−20.42	−21.30	−19.55	8.82***,[f]
Moderate transmission from humans to animals	14.30	13.30	15.29	17.65	16.55	18.75	−4.44***
High transmission from humans to animals	30.50	29.37	31.64	29.68	28.70	30.67	1.07[f]
Duration of illness in animals							
No illness observed or only a few days of illness	−20.34	−21.71	−18.98	−15.43	−16.61	−14.25	−5.34***,[f]
Short-term illness (weeks)	−8.66	−9.64	−7.67	−13.19	−14.37	−12.00	−5.76***,[f]
Medium-term illness (months)	3.33	2.16	4.50	1.49	0.52	2.45	2.38*,[f]
Chronic illness (years) or illness with permanent deficits	25.67	24.60	26.74	27.13	26.03	28.23	−1.85
Severity of illness in animals							
No apparent clinical signs or the animal source of infection is non-living (e.g. food source)	−22.93	−23.93	−21.93	−28.67	−29.79	−27.54	7.49***
Mild clinical signs (minor distress such as fever, lethargy, shivering, constipation, loose faeces)	−12.75	−13.57	−11.92	−16.06	−17.07	−15.05	4.98***,[f]
Moderate clinical signs (moderate distress such as difficult breathing, bleeding from openings, aborted foetuses)	9.18	8.10	10.25	11.06	9.78	12.34	−2.21*,[f]
Severe clinical signs (severe distress such as convulsion, organ failure, neurological involvement)	26.50	25.33	27.67	33.67	32.40	34.93	−8.1***
High-risk groups in humans							
No	−22.61	−23.61	−21.60	−14.97	−15.92	−14.03	−10.88***,[f]
Unknown	−3.22	−4.11	−2.34	−1.45	−2.46	−0.43	−2.61**
Yes	25.83	25.05	26.61	16.42	15.49	17.35	15.23***,[f]
How much is known scientifically about the disease							
Knowledge of the disease is well known and scientifically valid	−4.69	−7.16	−2.22	−5.68	−8.59	−2.77	0.51
Knowledge of the disease exists, but the validity of the information is uncertain	4.28	3.21	5.35	5.75	4.88	6.62	−2.09*,[f]
Knowledge of the disease is currently insufficient	5.85	4.62	7.08	1.38	0.01	2.75	4.77***
There is no scientific knowledge of the disease	−5.44	−6.72	−4.16	−1.45	−3.17	0.27	−3.65***,[f]
High-risk groups in animals							
No	−9.60	−10.54	−8.66	−10.71	−11.65	−9.77	1.64[f]
Unknown	−2.59	−3.41	−1.77	1.55	0.84	2.26	−7.50***,[f]
Yes	12.19	11.33	13.05	9.16	8.29	10.04	4.82***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

[a]Presented in order of importance to Canadian human health professionals.

[b]Mean part-worth utilities (β) across respondents.

[c]95% lower confidence interval (LCL) of mean part-worth utilities (β) across respondents.

[d]95% upper confidence interval (LCL) of mean part-worth utilities (β) across respondents

[e]t-statistic; $d.f.$ = 1282.

[f]Adjusted for unequal variance (identified by the F-test of equality of variances) using the Welch t-test.

Table 5. Disease priority list by human and animal health professionals

Human health professionals	Score	Rank	Animal health professionals	Score	Rank	Difference in rank[a]
Rabies	293.31	1	Rabies	272.49	1	0
Influenza (H1N1)	249.13	2	Nipah virus encephalitis	262.82	2	2
Listeriosis	220.81	3	Variant Creutzfeldt–Jakob disease (CJD)	260.85	3	3
Nipah virus encephalitis	214.02	4	Influenza (H1N1)	228.65	4	−2
Ebola virus haemorrhagic fever	151.30	5	Ebola virus haemorrhagic fever	207.83	5	0
Variant Creutzfeldt–Jakob disease (CJD)	149.68	6	Marburg haemorrhagic fever	199.76	6	1
Marburg haemorrhagic fever	139.82	7	Influenza (H5N1)	167.12	7	1
Influenza (H5N1)	89.81	8	Listeriosis	163.19	8	−5
Cryptosporidiosis	54.68	9	Botulism	46.58	9	2
Leishmaniasis	46.60	10	Hendra virus	39.02	10	6[b]
Botulism	45.10	11	Leishmaniasis	37.43	11	−1
Salmonellosis	19.04	12	Salmonellosis	21.85	12	0
Chlamydiosis	10.22	13	Escherichia coli infection	21.43	13	2
Tularaemia	2.88	14	Hantavirus pulmonary syndrome	14.54	14	6[b]
Escherichia coli infection	−3.97	15	Chlamydiosis	10.72	15	−2
Hendra virus	−5.65	16	Q fever	6.32	16	6[b]
Giardiasis	−7.41	17	Cryptosporidiosis	−1.22	17	−8[b]
American trypanosomiasis	−17.09	18	Brucellosis	−18.60	18	11[b]
Shigellosis	−24.31	19	Leptospirosis	−19.68	19	5
Hantavirus pulmonary syndrome	−25.01	20	Tularaemia	−27.34	20	−6[b]
Plague	−25.96	21	Giardiasis	−29.97	21	−4
Q fever	−29.59	22	Crimean−Congo haemorrhagic fever	−41.18	22	6[b]
Psittacosis/avian chlamydiosis	−34.62	23	American trypanosomiasis	−44.61	23	−5
Leptospirosis	−44.42	24	Plague	−50.53	24	−3
Toxoplasmosis	−53.35	25	Shigellosis	−58.47	25	−6[b]
Rocky Mountain spotted fever	−61.06	26	Paralytic shellfish poisoning	−61.91	26	11[b]
Eastern equine encephalitis	−77.85	27	Toxoplasmosis	−64.18	27	−2
Crimean-Congo haemorrhagic fever	−82.23	28	Psittacosis/avian chlamydiosis	−66.40	28	−5
Brucellosis	−84.76	29	Bartonellosis	−71.13	29	1
Bartonellosis	−87.20	30	Eastern equine encephalitis	−77.33	30	−3
Campylobacteriosis	−90.81	31	West Nile virus	−88.58	31	1
West Nile virus	−100.59	32	Lyme disease	−98.73	32	3
Echinococcosis	−108.39	33	Rocky Mountain spotted fever	−113.50	33	−7[b]
Anthrax	−115.40	34	Powassan virus	−119.56	34	4
Lyme disease	−119.92	35	Cutaneous larva migrans	−126.47	35	4
Toxocariasis	−131.43	36	Toxocariasis	−130.24	36	0
Paralytic shellfish poisoning	−132.41	37	Campylobacteriosis	−130.97	37	−6[b]
Powassan virus	−146.57	38	Echinococcosis	−131.83	38	−5
Cutaneous larva migrans	−163.41	39	Anthrax	−139.73	39	−5
Old/New World Screwworm	−175.36	40	Baylisascariasis	−157.79	40	1
Baylisascariasis	−183.47	41	Western equine encephalitis	−189.76	41	4
Anaplasmosis	−197.76	42	Severe acquired respiratory syndrome	−201.85	42	1
Severe acquired respiratory syndrome	−199.09	43	Old/New World Screwworm	−204.15	43	−3
Typhus	−206.48	44	Trichinosis	−217.03	44	3
Western equine encephalitis	−222.93	45	Anaplasmosis	−220.14	45	−3
Japanese encephalitis	−225.50	46	Typhus	−228.21	46	−2
Trichinosis	−231.50	47	Japanese encephalitis	−246.07	47	−1
Lassa fever	−263.37	48	Lassa fever	−252.07	48	0
Babesiosis	−270.21	49	Babesiosis	−253.64	49	0
Cholera	−279.58	50	Rift Valley fever	−260.51	50	2
Monkeypox	−280.25	51	Venezuelan equine Encephalitis	−285.11	51	2
Rift Valley fever	−318.64	52	Monkeypox	−293.12	52	−1
Venezuelan equine Encephalitis	−327.94	53	Bovine tuberculosis	−319.20	53	3
Yellow fever	−342.60	54	Cholera	−326.22	54	−4
Hepatitis A	−346.46	55	Yellow fever	−352.60	55	−1
Bovine tuberculosis	−369.60	56	Hepatitis A	−369.25	56	−1

Table 5. (Continued)

Human health professionals	Score	Rank	Animal health professionals	Score	Rank	Difference in rank[a]
Cysticercosis/taeniasis	−423.87	57	Cysticercosis/taeniasis	−420.87	57	0
Coccidioidomycosis	−437.99	58	Cyclosporiasis	−482.28	58	1
Cyclosporiasis	−453.62	59	Coccidioidomycosis	−490.22	59	−1
Dengue fever	−537.14	60	Dengue fever	−505.78	60	0
La Crosse encephalitis	−658.44	61	La Crosse encephalitis	−602.92	61	0
St. Louis encephalitis	−689.75	62	St. Louis encephalitis	−643.43	62	0

[a]Differences in ranks are calculated relative to human health professionals; a positive difference indicates the disease ranked higher in the animal health professional group, while a negative difference indicates the disease ranked higher in the human health professional group.
[b]Diseases that deviated by more than 5 ranked positions between human health and animal health professionals.

experts or end-user stakeholders. The use of CA in this study allowed individuals from different professions to participate because it presented participants with all the information they needed to prioritize diseases. Because of the diversity of the professionals involved, it was therefore not surprising that we identified differences between HHP and AHP. We found HHP placed more importance on human-related disease criteria while AHP placed higher importance on animal-related criteria in their decision to prioritize. These findings are supported by the initial focus groups that were conducted to inform this study (Ng and Sargeant, 2012b). The preference for animal-related criteria in the AHP and human-related criteria in the HHP resulted in unique priority lists for these groups. This is perhaps the most interesting aspect of this study, although we know that different stakeholders prioritize diseases differently according to their own personal and professional objectives, this study identified which disease criteria had the most influence and quantified those differences numerically using a revealed preference approach. The ability to quantify and understand why individuals prioritize diseases differently could aid in the disease prioritization process by allowing those involved to discuss the most divisive factors between groups and potentially come to consensus on a disease priority list after taking into account of those factors. Further, the findings from this study can guide decision-makers on the disease criteria that should be considered in any zoonotic disease prioritization process that has to be made in the absence of either of these professional groups. For example, when prioritizing zoonotic diseases with an objective that involves the combined impact on humans and animals, HHP decision-makers should consider the impact of animal-related criteria, principally, socio-economic burden in animals, severity of illness in animals, control measures in animals and animal-to-animal transmission. While these criteria may not directly impact on human health, they are important to AHP and excluding these criteria or downgrading their importance would produce a priority list that is inconsistent with the priorities of AHP. Similarly, AHP decision-makers should consider human-related criteria in their decision, particularly high-risk groups in humans, disease incidence in humans, human-to-human transmission and control measures in humans when considering their own priorities. In doing so, the concerns of stakeholders absent from the decision-making process can be addressed appropriately. Applying this reasoning to the disease priority list presented in this study, it becomes apparent why HHP and AHP prioritized diseases differently. For example, cryptosporidiosis was ranked eight positions higher by HHP than by AHP; this is likely due to a combination of high incidence in humans (important for HHP), low socio-economic burden in trade animals (important for AHP) and typically mild clinical signs in animals (also important for AHP). Conversely, Brucellosis was ranked 11 positions higher by AHP than by HHP, likely due to the joint impact of high socio-economic burden in trade animals, high animal-to-animal transmission potential, moderate severity of illness in animals and low human-to-human transmission potential. The same logic can be applied to the other diseases with large differences in ranks. Only by incorporating the importance of disease criteria from a range of professional groups can a disease priority list truly reflect the preferences of health professionals.

There are some limitations associated with this study. Although individuals were asked to prioritize for the control and prevention of zoonoses, they may have prioritized with other objectives in mind. Unfortunately, there is no way to measure this type of bias and we assume that participants were consistent with their prioritization objectives. We also used multiple recruitment methods to recruit participants (Ng and Sargeant, 2013); it is unknown whether different recruitment methods produced different results. We assume participants responded to the survey in the same manner regardless of their mode of recruitment. Finally, at the time of the literature search, there was a lack of data for some disease criteria pertaining to specific diseases (Sargeant and Ng, 2011). It is unknown the impact this uncertainty may have had on the current results. However, the best available data at the time of study implementation were used to inform this study.

We conducted a zoonoses prioritization study involving a wide range of health professionals in North America. We showed that CA could be used to produce reasonable disease criteria scores and part-worth utilities; further, the models could be validated using post-estimation goodness-of-fit tests. Human-related criteria were more influential for HHP in their decision to prioritize zoonoses, while animal-related criteria were the dominant drivers for AHP; this resulted in different disease priority lists between the two groups. We identified and quantified disease criteria that had the strongest influence in the decision to prioritize, and these findings aid in our understanding of why HHP and AHP prioritize diseases differently and can inform future prioritization exercises when either groups cannot be involved. Our findings highlight the importance of engaging a range of health professionals in the disease prioritization process to ensure that all priorities are addressed and that disease priority lists are representative of all affected stakeholders. The scientific framework for disease prioritization described in this study can be revised on a regular basis by updating criteria levels to match diseases to their most current trends; such a framework is of value to North America allowing diseases with the highest impact and threat to be identified routinely in order to allocate resources for their prevention and control.

Ethics approval

The University of Guelph Research Ethics Board granted ethical approval for all aspects of this study (Protocol #10MY014).

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