Factors associated with euthanasia in horses and ponies enrolled in a laminitis cohort study in Great Britain

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Abstract

Euthanasia is a complex topic, with animal owners using multiple factors to shape their decision-making process. Previous epidemiological studies have described causes of equine mortality in specific populations, but there is limited evidence regarding factors contributing specifically to equine euthanasia in Great Britain (GB).

This observational study used a prospective cohort design: the objectives were to describe owner-reported reasons for euthanasia, estimate the rate of euthanasia and identify associated factors in horses/ponies enrolled in a web-based epidemiological study of laminitis in GB.

Self-selected horse/pony owners submitted regular management and health data over 9 months and reported dates and reasons for euthanasia during this period. The overall incidence of euthanasia was estimated and associated factors were identified using multivariable Cox regression modelling, adjusted for age, with variables retained in the final model if $P \leq 0.05$.

Data were available for 1,070 horses/ponies contributing 1,093 horse-years at risk (HYAR), with 80 owner-reported euthanasias. The incidence of euthanasia was 7.3 euthanasias per 100 HYAR (95% confidence interval [CI] 5.9, 9.1). The most frequently reported health reasons contributing to euthanasia were laminitis-related consequences (25.0%; CI 16.8, 35.5%), colic (21.3%; CI 13.7, 31.4%), non-laminitic lameness (20.0%; CI 12.7, 30.1%) and age-related deterioration, including owner-perceived compromised quality of life (20.0%; CI 12.7, 30.1%). Health-related factors associated with significantly higher rates of euthanasia were colic (hazard ratio [HR] 26.4; CI 12.5, 55.8), pituitary *pars intermedia* dysfunction (HR 3.0; CI 1.7, 5.4) and lameness due to navicular syndrome (HR 5.9; CI 1.8, 20.0), soft tissue injury (HR 6.5; CI 2.7, 15.6) or laminitis (HR 2.7; CI 1.3, 5.7). Further factors included being pure bred (HR 1.7; CI 1.0, 2.8), female (HR 1.7; CI 1.0, 2.9), having poor owner-perceived hoof quality (HR 2.4; CI 1.1, 5.2), being entirely stabled (HR 5.0; HR 2.1, 12.0), being on

loan or under temporary care of the study participant (HR 2.3; CI 1.2, 4.4) and participating in affiliated or professional competitions (HR 5.9; CI 2.4, 14.8). Euthanasia rates were significantly higher in the first two study years compared to the third (P<0.001). Animals whose owners used the study's custom-designed weight tracker tool had significantly lower rates of euthanasia (HR 0.6; CI 0.3, 0.95).

This study has identified a number of, arguably preventable, health-related factors associated with higher rates of euthanasia. Data on owners' decision-making process regarding euthanasia, including emotive and financial impacts, were not recorded but are important contributors to euthanasia that require better understanding.

Keywords

Equine; incidence rate; Cox regression; end of life; quality of life; mortality

1. Introduction

Euthanasia is available to the veterinary surgeon when assisted death is believed to be in the best interests of the animal's welfare relative to other possible options (Yeates, 2010). In fact, delaying euthanasia when it is considered necessary has considerable ethical and welfare implications (Rollin, 2011). Euthanasia is a complex and emotive topic, with animal owners using multiple factors to shape their decision-making process (Marchitelli, 2019). Owners of aged horses and ponies ranked veterinary advice, health conditions with a poor prognosis or those causing prolonged pain/stress and the animal's anticipated quality of life (QoL) as the most important factors influencing their decision to euthanase (McGowan et al., 2012). Similarly, the most important factor influencing an owner's decision to undertake expensive and long-term veterinary care was their geriatric animals' QoL, while financial cost ranked lowest (Mueller et al., 2018). These influencers are important to consider when discussing management and health-related factors associated with euthanasia. While it is not in the animals' interest to reduce rates of appropriate euthanasia, understanding the epidemiology of euthanasia can help prioritise research into life-threatening conditions that are potentially preventable.

Equine mortality (aside from humane slaughter), is usually described as being either due to unassisted natural death or euthanasia. Mortality has been well described in racehorses (Johnson et al., 1994; Williams et al., 2010; Lyle et al., 2011; Rosanowski et al., 2017; Wylie et al., 2017; Hitchens et al., 2019; Physick-Sheard et al., 2019), yet mortality data in the non-racing population is limited to foals (Cohen, 1994; Haas et al., 1996; Morley and Townsend, 1997), aged horses/ponies (Ireland et al., 2011b; Miller et al., 2016), insured horses/ponies (Leblond et al., 2000; Penell et al., 2005; Egenvall et al., 2006; Bonnett and Egenvall, 2010), riding school animals (Egenvall et al., 2009) and Swedish Warmblood and coldblooded horses (Wallin et al., 2000). Diseases of the digestive system and lameness have been

reported as the most common reasons for mortality in non-racing adult equine populations (Egenvall et al., 2006; Ireland et al., 2011b; Miller et al., 2016; Tapprest et al., 2019). However, there is limited evidence regarding factors contributing specifically to equine euthanasia.

In Great Britain (GB), 94% of geriatric (≥15 years) equine mortalities were attributed to euthanasia rather than unassisted natural death (Ireland et al., 2011b) suggesting that improved knowledge of the incidence and factors associated with euthanasia can help focus future qualitative and quantitative health- and welfare-related research. Following a cohort of horses and ponies to determine which ones developed equine laminitis, a systemic disease resulting in lameness, presented an opportunity to explore the epidemiology of euthanasia within this age unrestricted population (Pollard et al., 2019). The objectives of this prospective cohort study were to i) describe owner reported reasons contributing to euthanasia, ii) estimate the overall rate of euthanasia and iii) identify factors associated with euthanasia in horses/ponies enrolled in a web-based epidemiological study of laminitis in GB.

2. Material and methods

2.1. Study population and study period

The study population included horses and ponies enrolled in a web-based prospective cohort study of equine laminitis in GB between August 2014 and December 2016. The nature of the cohort was dynamic, in that animals were enrolled into and could leave the study at any point during the 29 month study period, although efforts were made to retain animals for as long as possible. Description of recruitment and retention methods are available elsewhere (Pollard et

al., 2019b, 2019a). In brief, self-selected horse/pony owners or carers from England, Scotland and Wales were actively recruited between August 2014 and July 2016, irrespective of whether or not their animal had a history of laminitis. Owners were made aware of the study nationally via traditional and social media, veterinary practices, other equine health care practitioners, equine charities, breed organisations, owner information evenings, face-to-face conversations at equestrian events and word-of-mouth from existing participants. Regular competitions and prize draws were held during the study to aid with recruitment and retention. A dedicated website was used for enrolment and subsequent data collection.

2.2. Study design, data collection and sample size estimation

Owners submitted an online baseline management and health questionnaire (Additional file 1) for each horse/pony upon enrolment, with consecutive prospective follow-up questionnaires every one to three months until the animal exited the study. Baseline questionnaire submission signalled the entry of a horse/pony into the study. Exit from the study for each animal was the day after the last follow-up submission or the day of death by any means. Time at risk was calculated as horse-years at risk (HYAR) and defined as the total time each animal contributed to the study, from enrolment until they were euthanased, died an unassisted natural death or did not have the outcome of interest by the time their last follow-up was submitted. Monthly automated personalised reminders were sent via e-mail to all enrolled owners. Manual e-mails were sent to owners that had not submitted follow-ups for more than three months. Further details on study design and data collection are published elsewhere (Pollard et al., 2019a, 2019b). The questionnaire consisted of eight sections of predominantly tick-box questions detailing the animal's signalment, current diet, exercise, hoof care, transport, routine health care and recent and historical health (Pollard et al.,

2019b), and was based on a previous self-administered owner questionnaire (Wylie et al., 2013a). An online weight tracker tool (Pollard et al., 2019b) was developed to monitor changes in body condition score (BCS) using a modified Carroll and Huntington 6-point BCS scale (Carroll and Huntington, 1988) and estimated body weight (BW) using anatomical measurements (Wagner and Tyler, 2011). For each animal, BW estimates were automatically plotted graphically for owner visualisation. Owners reported unassisted natural death or euthanasia via the questionnaire or by directly contacting the study team, with the option of providing associated health-related reasons. Sample size estimation (OpenEpi v3.03)[1], assuming 95% confidence level, 80% power, an exposure prevalence range of 5% to 30%, a euthanasia prevalence of 7% based on lower expected frequency compared to the geriatric population (Ireland et al., 2011b) and allowing for 20% loss to follow-up, indicated that at least 1,000 HYAR were necessary to detect a minimum effect size of 2.0 across exposures. The study was approved by the Animal Health Trust (AHT01–2014) and Royal Veterinary College (2014 0105H) Ethics Committees.

2.3. Data analyses

A secure structured query language database stored the collected data, which was exported into Microsoft Excel (v.2010)[2] for initial cleaning and processing. All coding and statistical analyses were conducted in Stata (IC v.15.0)[3]. Continuous variables were visually assessed for normality of distribution and presented as means ±standard deviations or medians and interquartile ranges (IQR). Categorical variables were presented as proportions with 95% confidence intervals (CI). A binary outcome variable indicated whether euthanasia occurred

[1] Dean, A.G., Sullivan, K.M., Soe, M.M. OpenEpi: Open Source Epidemiological Statistics for Public Health, Version. www.OpenEpi.com, updated 2013/04/06.
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[3] StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC.

or did not occur for each horse/pony for the duration of time they were under observation. The '*stset*' Stata command (StataCorp., 2017) was used to specify that data were survival-time data and enabled analysis of sequential multiple records for each animal which coincided with the period of time over which the animal was observed. Missing data remained missing except where owner-reported animal age was used to estimate a date of birth. Where only partial date of birth information was available, the date was set to either the first day of the month provided or the first of January if only the year was provided. To adjust for the continuous effect of age on euthanasia risk over time (Egenvall et al., 2006; Ireland et al., 2011b), a horse/pony was considered at risk of euthanasia on the day they were born, came under observation when they entered the study and remained at risk each day they were actively enrolled in the study. Owner-reported health reasons that contributed to euthanasia were categorised and described. An overall euthanasia rate, and corresponding 95% CI, was estimated and expressed per 100 HYAR.

Multivariable Cox regression modelling (Cox, 1972) was used to conduct time to event analysis as per previously published methods (Pollard et al., 2019b). In brief, variables associated with euthanasia at a level of P<0.25 (likelihood ratio test) in univariable analyses were used to create eight interim multivariable models, based on questionnaire sections, using manual forward stepwise selection (Wylie et al., 2013; Pollard et al., 2019). Variables were retained in the interim models if the likelihood ratio statistic (LRS) P≤0.05. The interim models were combined to develop a final multivariable model with variables retained if the LRS P≤0.05. Variables significant during univariable and interim modelling, but not retained in the final model, were forced back in to ensure that significant or confounding relationships between variables were not omitted. Two-way interactions considered biologically plausible were assessed between variables in the final model using the likelihood ratio test and retained

where LRS P≤0.05. Owner-level clustering was assessed using the *vce (cluster owner_id)* Stata option (StataCorp, 2017). Post-fit diagnostics included evaluation of model fit using partial Cox-Snell residuals (StataCorp, 2017), the identification of outliers using partial deviance residual plots and identifying influential observations using partial likelihood displacement values (Collett, 2015). The model was refitted excluding outliers and influential observations to assess the effect on model parameter estimates. Kaplan-Meier estimates of cumulative survival probability over study time in days, including 95% CI, were plotted for health-related factors found to be significantly associated with euthanasia.

3. Results

3.1 Descriptive data and euthanasia rates

A total of 6,995 questionnaire submissions, representing 1,070 horses/ponies and 1,093 HYAR were available for analysis. Median submissions per horse/pony were 4 (IQR 2 to 9 submissions) with a median of 33 days (IQR 2[illegible] to 53 days) between submissions. The demographics of the cohort population at baseline are described in detail elsewhere (Pollard et al., 2019b). In brief, a median of 2 horses/ponies (IQR 1 to 3 horses/ponies) were enrolled per owner and the median duration of ownership/care was 6.7 years (IQR 2.5 to 11.9 years). Geldings (57.5%; CI 54.5, 60.4%) were the predominant sex and native ponies (40.7%; CI 37.8, 43.7%) were the largest breed category. Median height was 147.3cm (IQR 135.9 to 157.5cm) while mean owner-reported age was 14.7 years (±6.9 years; range 1 to 38 years). The majority of horses/ponies (59.0%; CI 56.0, 61.9%) were reported to be in ideal body condition (3/5 BCS). Owners reported that 35.9% (CI 33.0, 38.7%) of horses/ponies had laminitis previously whilst in their care.

Overall, 82 mortalities were reported during the study period, with 80 (97.6%; CI 91.5, 99.3%) attributed to euthanasia and two to sudden death in the field/stable from suspected, but not confirmed, cardiac failure. Out of 988 horses/ponies that survived while under observation, 466 (47.2%) were followed-up until the last three months of the study period while 52.8% exited the study prior to this time. The most frequently reported health reasons for euthanasia (Table 1) were laminitis-related consequences (25.0%), colic (21.3%), non-laminitic lameness (20.0%) and age-related deterioration including owner-perceived compromised QoL (20.0%). The median age at euthanasia was 20.0 years (IQR 15.0 to 25.5 years, range 5 to 33 years). The overall incidence rate of euthanasia was 7.5 euthanasias per 100 HYAR (CI 5.9, 9.1).

3.2 Cox regression analysis

All variables considered for inclusion in the multivariable interim models are presented in Additional file 2, with interim models presented in Table 2. The signalment and environment interim model identified euthanasia was associated with study year, online weight tracker use, breed category and BCS. The health interim model identified vaccination status, colic, box rest, lameness and pituitary *pars intermedia* dysfunction (PPID) were associated with euthanasia. The hoof care interim model identified soreness after shoeing/trimming and owner-perceived hoof quality were associated with euthanasia. The stabling and turnout interim models identified euthanasia was associated with time spent stabled, type of grazing and co-grazing with goats. Finally, feeding and exercise interim models identified euthanasia was associated with hormone supplements, current feeding goal, hacking activity and

professional/affiliated sport competing. Associations were not identified between euthanasia and any of the transport-related variables.

3.3 Final multivariable Cox regression model

The final multivariable model contained 13 variables associated with euthanasia (Table 3). Type of ownership and sex, which were excluded during the interim model building, were retained in the final model as they significantly improved model fit. Additionally, the 'average' and 'good' categories of the owner-perceived hoof quality variable were combined into a single category due to having similar effect sizes when compared to the 'poor' category. Therefore, in brief, variables associated with higher euthanasia rates included factors related to **signalment and environment**: (i) the first two study years vs. the third, (ii) animals under temporary care by the study participant vs. those owned, (iii) pure breed vs. cross breed animals, (iv) females vs. males; **health**: (v) colic in the previous month, (vi) existing PPID diagnosis, (vii) lameness due to navicular syndrome, (viii) lameness due to soft tissue injury, (ix) remaining lame following the most recent laminitis episode vs. being sound; **hoof care**: (x) poor owner-perceived hoof quality vs. average or good owner-perceived hoof quality; **stabling and turnout**: (xi) being entirely stabled vs. having access to turnout and **exercise**: (xii) competing at affiliated level or professionally vs. not competing at that level or not. Animals whose owners used the study's online weight tracker tool had a reduced rate of euthanasia compared to animals whose owners did not.

No significant interactions were identified between variables in the final multivariable model. Removal of highly influential observations and individuals had no considerable effect on

model parameter estimates, thus all observations and individuals were retained in the final model. All variables retained significance following adjustment of standard errors to account for owner-level clustering, therefore no adjustments were made. Kaplan-Meier estimates of survival probability, stratified by health conditions significantly associated with euthanasia, are shown in Figure 1.

4. Discussion

These findings provide equine mortality data that strengthen the evidence-base regarding reasons contributing to equine euthanasia and the overall rate of euthanasia in GB. Furthermore, this study has identified a number of, arguably preventable, health-related factors associated with higher rates of euthanasia in horses/ponies.

The demographics of this study population are largely similar to those previously described in other GB equine populations (Hotchkiss et al., 2007; Ireland et al., 2011a; Wylie et al., 2013a, 2013b). Few equine studies report the distinction between unassisted natural death and euthanasia when describing mortality, making it difficult to compare the euthanasia rate in the current study (7.3/100 HYAR) with previously reported estimates. A cohort study of factors associated with mortality in a population of geriatric horses/ponies (≥15 years) in GB found that 111/859 geriatric horses/ponies were euthanased, from which an estimated euthanasia rate of 10.4 per 100 HYAR (95% CI 8.6, 12.5) could be calculated (Ireland et al. 2011b). This slightly higher estimate likely reflects the older population in the previous study. As ageing is an intrinsic determinant of mortality risk (Egenvall et al., 2006; Ireland et al., 2011b), it was adjusted for in our regression modelling from the start. The majority of

horses/ponies experiencing mortality in the current study were euthanased, with only 2/82 (2.4%; 95% CI 0.67%, 8.5%) reported to have been found dead. This is similar to findings by Ireland et al. (2011b) where only 7/118 (5.9%; 95% CI 2.9%, 11.7%) died naturally as opposed to being euthanased.

Laminitis was the most common reason contributing to euthanasia in our study population, in which 36% of horses/ponies were reported to have a history of laminitis. The main purpose of the cohort study was to investigate the epidemiology of equine laminitis and the self-selected enrolment into the study may have introduced selection bias, although previously reported laminitis frequency estimates range from 1.5% to 34.0% (Wylie et al., 2011). Additionally, a large UK study using first-opinion veterinary practice records from 70,477 horses/ponies found that those with a laminitis diagnosis had a six-fold increase in mortality rate compared to animals with no chronic disease (Welsh et al., 2016). Laminitis was also present in 74% of multimorbidity cases involving other chronic diseases associated with higher mortality rates in the study by Welsh et al. (2016), suggesting that laminitis is likely to be an important contributor to euthanasia in the general veterinary-attended equine population. In the current study, colic and (non-laminitic) lameness were the next most prevalent health-related reasons contributing to euthanasia, similar to previously-published equine mortality data (Egenvall et al., 2006; Ireland et al., 2011b; Miller et al., 2016; Tapprest et al., 2019). A considerable proportion of owners in the current study also reported that age-related deterioration and concerns about their animal's QoL, often alongside other comorbidities, were important contributors to euthanasia which is in keeping with factors influencing euthanasia identified by Ireland et al. (2011b). The finding that euthanasia rates were higher in the first two study years (2014 [August to December] and 2015) compared to the third (2016) likely reflects the recruitment of animals with a history of laminitis at the start of the study. Enrolment of

animals with a history of laminitis was highest in the first study year (41.6%), compared to subsequent years (31.3% and 33.6%, respectively). Additionally, half of the euthanasias in the first study year were due to laminitis-related consequences while non-laminitic lameness and colic were the main reasons contributing to euthanasia in the subsequent years. This variation in euthanasia-related reasons could, therefore, have been influenced by variation in demographic characteristics over the study period.

Sex and breed were associated with euthanasia in this population, with females and pure bred animals more likely to be euthanased than males and cross breeds, respectively. Previous studies have reported conflicting evidence of a common sex effect on mortality, suggesting it may be country, breed and use dependent (Egenvall et al., 2006; Leblond et al., 2000; Wallin et al., 2000; Ireland et al., 2011b). One suggestion for a higher risk of mortality in mares has been reproductive complications, particularly during foaling (Leblond et al., 2000). However, the horses/ponies in this study were mainly used for leisure and competition purposes or as companions, with very few being used for breeding. Breed-specific differences in mortality rates have previously been reported (Egenvall et al., 2006; Ireland et al., 2011b). However, while the longevity of cross breeds over pure breeds has been described in cats and dogs (O'Neill et al., 2013, 2015), this has not previously been demonstrated in equids.

This study identified a number of key, and potentially preventable, disease processes associated with euthanasia. Horses/ponies with acute abdominal pain, or colic, in the previous month had significantly higher rates of euthanasia compared to animals with no reported colic in the same timeframe. Colic is a considerable, and often recurrent, welfare concern with the recurrence of medical episodes of colic in a population of UK horses estimated at 50

colic events/100 HYAR (Scantlebury et al., 2011). Colic was the second most common reason contributing to euthanasia in this study, occurring shortly prior to the animal being euthanased. Colic surgery is a high-risk and expensive procedure which carries a considerable risk of post-operative complications (Barker and Freeman, 2019; Immonen et al., 2017), factors which likely influence euthanasia in affected animals. A recent study in the UK investigated financial costs of treating referral colic cases with reference to cover provided by five existing insurance policies, reporting an often significant gap between the cover and the ultimate cost of surgical treatment (Barker and Freeman, 2019). Additionally, all policies included a range of age-related exclusions, with illness no longer covered in animals older than 20 to 25 years of age which may further contribute to euthanasia in aged horses with colic requiring surgical intervention. Recall bias may have been introduced through owners whose animals were euthanased due to colic being more likely to recall and report the colic, compared to reporting of mild colic episodes not requiring veterinary treatment or surgical intervention (Scantlebury et al., 2014).

Horses/ponies that remained lame following their most recent episode of laminitis were more likely to be euthanased compared to animals that recovered soundness or those that never had laminitis. Mortality in horses with laminitis is associated with factors related to disease stage, severity and progression (Cripps and Eustace, 1999; Menzies-Gow et al., 2010; Orsini et al., 2010). Longer recovery time from a previous episode of laminitis, judged by an owner-perceived return to soundness, was associated with higher rates of future laminitis development in this population of horses/ponies (Pollard et al., 2019b). Although the severity of lameness was not assessed in this study, prolonged episodes of unresolved and recurrent lameness, and the substantial amount of time animals may have to spend confined during recovery, could negatively affect psychological wellbeing and QoL, contributing to an

owner's decision to have their animal euthanased (Ireland et al., 2011b; McGowan et al., 2012; Mueller et al., 2018). This may be reflected by the finding that animals that were entirely stabled had higher rates of euthanasia compared to animals with some access to turnout. Similarly to colic (Curtis et al., 2019), modifiable management factors associated with laminitis development have been identified, offering potential practical strategies to assist with disease prevention (Wylie et al., 2013a; Luthersson et al., 2016; Pollard et al., 2019). These results confirm that colic and laminitis remain important contributors to equine euthanasia in Great Britain.

Non-laminitic lameness, due to either owner-reported navicular syndrome or soft tissue injury, was associated with higher rates of euthanasia in this study. Navicular syndrome is a chronic progressive lameness caused by pathologies of the podotrochlear apparatus (comprised of the distal sesamoid [navicular] bone and associated ligaments), with or without additional compromise of the deep digital flexor tendon and adjacent joints (Dyson et al., 2011). Injury or disease may affect one or multiple structures making navicular syndrome difficult to differentiate clinically from other causes of foot pain (Parkes et al., 2015). Few effective long-term treatment options are available, with affected animals potentially remaining chronically lame and unable to perform, or return to, high-impact athletic activities (Dyson et al., 2005; Marsh et al., 2012). Where details of soft tissue injury were provided (21 cases), the majority (62%) were described as tendon and ligament injuries. These injuries are known to require long periods of recovery and rehabilitation, with high risk of re-injury (Ortved, 2018; McClellan et al., 2019); re-injury rates of up to 67% have previously been reported (Dyson, 2010). Lameness remains an important contributor to equine euthanasia in the general equine population of Britain; particularly potentially chronic lameness which is

influenced by limited analgesic options, financial implications and loss of athletic performance or intended use.

Animals that were reported to have poor hoof quality were more likely to be euthanased compared to animals that had average or good hoof quality. Hoof horn quality and the presence of hoof disorders can be influenced by external factors such as nutrition, bedding, stress and hoof care routine (Dyson et al., 2011; Holzhauer et al., 2017) as well as genetic predisposition (Finno et al., 2015). In the current study, presence of hoof wall cracks, white line disease and thrush, although associated with euthanasia in univariable analyses, were not retained in the final model. It may be that owner assessment of poor hoof quality collectively better represented multifactorial hoof disorders that compromised mobility, led to poor long-term welfare, intensive management and considerable veterinary and farriery costs.

The presence of veterinary-diagnosed PPID, an age-related progressive degeneration of dopaminergic neurons affecting the *pars intermedia* of the pituitary gland (McFarlane, 2011), was associated with higher rates of euthanasia. Post-mortem findings from equids ≥15 years at a US teaching hospital revealed that disease of the pituitary gland was the second most common contributor to mortality (Miller et al., 2016). Presence of PPID was associated with a lower probability of survival and shorter survival time following diagnosis than for other chronic diseases investigated in a GB study using veterinary practice records (Welsh et al., 2016). Concurrent insulin dysregulation (ID) was diagnosed in 77% of animals with PPID (Horn et al., 2018), placing them at higher risk of developing laminitis (de Laat et al., 2015, 2019). While PPID is not currently preventable, treatment and management modalities to improve clinical signs, reduce adverse outcomes and prolong survival exist (McFarlane et al., 2017; Horn et al., 2018). Prompt recognition of PPID, alongside appropriate treatment and

management, may reduce the impact of the condition. However, ultimately PPID is an age-related progressive condition which will likely continue to substantially contribute to euthanasia due to the increasing life expectancy of horses and ponies (Mellor et al., 1999; Hotchkiss et al., 2007; Ireland et al., 2011a; Welsh et al., 2016).

Horses/ponies being cared for as part of a loan agreement (either privately or through an equine re-homing charity) or through job-related care (resident at an equine charity centre or equine college) had higher euthanasia rates compared to those owned by the study participant. This 'loaned' group of horses/ponies likely differ from the general horse population and the decision-making process surrounding euthanasia in this sub-population may be substantially different from that of privately owned animals. For example, 57.6% of loaned horses/ponies were non-ridden at baseline compared to 30.2% of privately owned animals. Horses/ponies participating in affiliated and professional sport competitions were also more likely to be euthanased. High-activity competition animals are likely to be more prone to severe musculoskeletal injuries during ridden exercise, but also potentially in the field, leading to acute or chronic lameness (Owen et al., 2012; Inness and Morgan, 2015; Hitchens et al., 2019). However, it may also reflect the financial burden of sustained veterinary treatment or of keeping a horse or pony that can no longer perform their perceived task.

Animals of owners who used the study's weight tracker tool had a reduced rate of euthanasia compared to animals of owners who did not. The routine visual representation of BW estimates and BCS over time could have alerted owners to unwanted weight loss. Owner-reported underweight body condition has previously been associated with higher mortality in

geriatric horses/ponies (Ireland et al., 2011b) and remained in the multivariable interim model in this study alongside a feeding goal which aimed to increase BW. However, neither of these variables was retained in the final model, potentially due to inclusion of health-related conditions contributing to changes in biochemical parameters and poor nutrient uptake, such as PPID. It is likely the weight tracker use was a proxy for another owner- or management-related factor that was not directly measured in the current study.

Euthanasia is a complex and emotive topic. While the factors which shape the decision-making process and the appropriateness of euthanasia in each case were not investigated, they should be kept in mind when discussing these animal-level factors. Although a number of identified factors are consistent with previous equine mortality-based studies, some may be proxy measures for additional factors not identified here or likely reflect the current incompletely understood interactions between disease progression, prognostication by attending veterinary surgeons and the complexities around owners' euthanasia decision making. For example, financial cost of treatment and insurance status are likely important influencers on whether owners opt for euthanasia even when treatment options are available and post-treatment prognosis is good (Kipperman, 2010). All data were owner-reported and the level of detail regarding reasons contributing to euthanasia was often broad, but the factors associated with euthanasia identified matched the reasons reported – with laminitis, colic and non-laminitic lameness being major contributors. Complete agreement has previously been found between the majority of veterinary recorded and owner-reported reasons for euthanasia (Ireland et al., 2011b) indicating that owner-reported reasons for euthanasia are generally reliable.

5. Conclusions

This study has identified a number of, arguably preventable, health-related factors associated with higher rates of euthanasia. Further qualitative equine euthanasia studies should be carried out in different populations of horses and ponies, and owner types, to further inform the multifactorial nature of the euthanasia decision-making process.

Conflict of interest statement

The authors declare that they have no competing interests.

Author contributions

All authors contributed to the study design; the data were collected by DP; statistical analysis, interpretation and preparation of the manuscript were performed by DP, with input from CEW, JRN and KLPV; all authors approved the final version.

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Tables

Table 1

Owner-reported health reasons contributing to euthanasia in horses and ponies enrolled in a laminitis cohort study in Great Britain between August 2014 and December 2016 (n=80).

Health reason contributing to euthanasia*	**Frequency**	**Percent**	**95% CI**
Laminitis-related consequences	20	25.0%	16.8, 35.5%
Colic	17	21.3%	13.7, 31.4%
Non-laminitic lameness	16	20.0%	12.7, 30.1%
Osteoarthritis	*8*	*50.0%*	

Health reason contributing to euthanasia*	Frequency	Percent	95% CI
Undefined lameness	*4*	*25.0%*	
Navicular syndrome	*3*	*18.8%*	
Tendon/ligament injury	*1*	*6.3%*	
Age-related deterioration	16	20.0%	12.7, 30.1%
Endocrine-related complications	13	16.3%	9.8, 25.8%
Neurological	4	5.0%	2.0, 12.2%
Respiratory	4	5.0%	2.0, 12.2%
Neoplasia	4	5.0%	2.0, 12.2%
Cardiac	3	3.8%	1.3, 10.5%
Other	7	8.8%	4.3, 17.0%
Hepatic	*2*	*28.6%*	
Sepsis	*2*	*28.6%*	
Not reported	*3*	*42.8%*	

*Categories were not mutually exclusive as more than a third of owners reported multiple comorbidities.

Table 2

Interim multivariable Cox regression model for factors associated with euthanasia (n=80 cases) and adjusted by age, in a cohort study of horses and ponies in Great Britain (1,058 horses/ponies; 6,966 observations; 1,093 horse-years at risk [HYAR]).

Variable	No. of euthanasias	HYAR /100	Hazard ratio	95% CI	Wald P-value	LRS# P-value
Signalment and environment						
Study year						*0.001*
1 (Aug – Dec 2014)	8	0.6	3.2	1.4, 7.2	0.005	
2 (Jan – Dec 2015)	34	3.5	2.2	1.4, 3.6	0.001	
3 (Jan – Dec 2016)	38	6.9	Ref.			
Weight tracker use						*0.005*

Variable	No. of euthanasias	HYAR /100	Hazard ratio	95% CI	Wald P-value	LRS# P-value
No	47	5.4	Ref.			
Yes	33	5.6	0.5	0.3, 0.8	0.005	
Breed category						*0.03*
Cross breed/unknown	35	5.7	Ref.			
Pure breed	45	5.3	1.6	1.0, 2.6	0.04	
Body condition score (BCS)						*0.05*
Ideal (BCS = 3)	47	7.1	Ref.			
Underweight (BCS < 3)	18	1.0	2.1	1.1, 3.7	0.02	
Overweight (BCS > 3)	15	2.8	0.9	0.5, 1.6	0.71	
Health						
Vaccination status						*0.02*
Vaccinated	71	10.2	Ref.			
Not vaccinated	8	0.6	2.8	1.3, 6.2	0.10	
Colic in the previous month						*<0.001*
No	62	10.7	Ref.			
Yes	18	0.2	22.0	11.0, 44.1	<0.001	
Current box rest						*0.03*
No	73	10.7	Ref.			
Yes	7	0.2	3.1	1.3, 7.6	0.01	
Lameness due to soft tissue injury						*0.001*
No	73	10.7	Ref.			
Yes	7	0.2	5.3	2.2, 12.6	<0.001	
Lameness due to navicular syndrome						*0.02*
No	76	10.8	Ref.			
Yes	4	0.1	5.1	1.6, 16.0	0.006	
Pituitary pars intermedia dysfunction						*0.001*
No	40	8.6	Ref.			
Yes	40	2.4	3.3	1.4, 4.2	<0.001	
Lameness following laminitis episode						*0.006*
Became sound/no previous laminitis	66	10.5	Ref.			
Stayed lame	14	0.5	3.0	1.4, 6.2	0.004	
Hoof care						
Soreness after shoeing/trimming						*0.001*
No	65	10.3	Ref.			
Yes	15	0.6	3.1	1.7, 5.7	<0.001	
Hoof quality						*0.05*
Good	37	7.3	Ref.			
Average	32	2.9	1.5	0.9, 2.5	0.14	
Poor	10	0.6	2.5	1.2, 5.2	0.02	
Turnout and grazing management						
Turnout routine						*<0.001*
Entirely/partly turned out	70	10.6	Ref.			
Entirely stabled	10	0.3	7.7	2.6, 22.5	<0.001	
Type of grazing						*0.01*
Mature/newly seeded grass paddock	16	4.1	Ref.			

Variable	No. of euthanasias	HYAR /100	Hazard ratio	95% CI	Wald P-value	LRS[#] P-value
Meadow pasture	48	5.7	0.4	0.2, 0.8	0.005	
Other/no grass	16	1.1	0.8	0.3, 1.8	0.54	
Co-grazing with goats						*0.003*
No	76	10.7	Ref.			
Yes	4	0.1	8.1	2.7, 24.5	<0.001	
Stabling and indoor environment						
Time spent stabled						*0.008*
Up to 3 hours	33	5.6	Ref.			
More than 3 and up to 12 hours	24	2.7	1.6	0.9, 2.7	0.10	
More than 12 and up to 23 hours	17	2.3	1.1	0.6, 2.0	0.86	
More than 23 hours	6	0.2	5.8	2.3, 14.5	<0.001	
Feeding						
Hormone supplements						*0.005*
No	71	10.5	Ref.			
Yes	9	0.4	3.3	1.6, 6.8	0.001	
Current feeding goal						*0.03*
To decrease/maintain weight	69	10.3	Ref.			
To increase weight	11	0.6	2.3	1.1, 4.5	0.02	
Exercise						
Hacking activity						*0.003*
No	52	4.9	Ref.			
Yes	28	6.0	0.5	0.3, 0.8	0.004	
Professional/affiliated sport competing						*<0.001*
No	72	10.5	Ref.			
Yes	8	0.5	5.9	2.6, 13.7	<0.001	
Transport						
None identified						

[#] Likelihood ratio statistic

Table 3

Final multivariable Cox regression model for factors associated with euthanasia (n=79 cases) and adjusted for age, in a cohort study of horses and ponies in Great Britain (1,042 horses/ponies; 6,923 observations; 1,084 horse-years at risk [HYAR]).

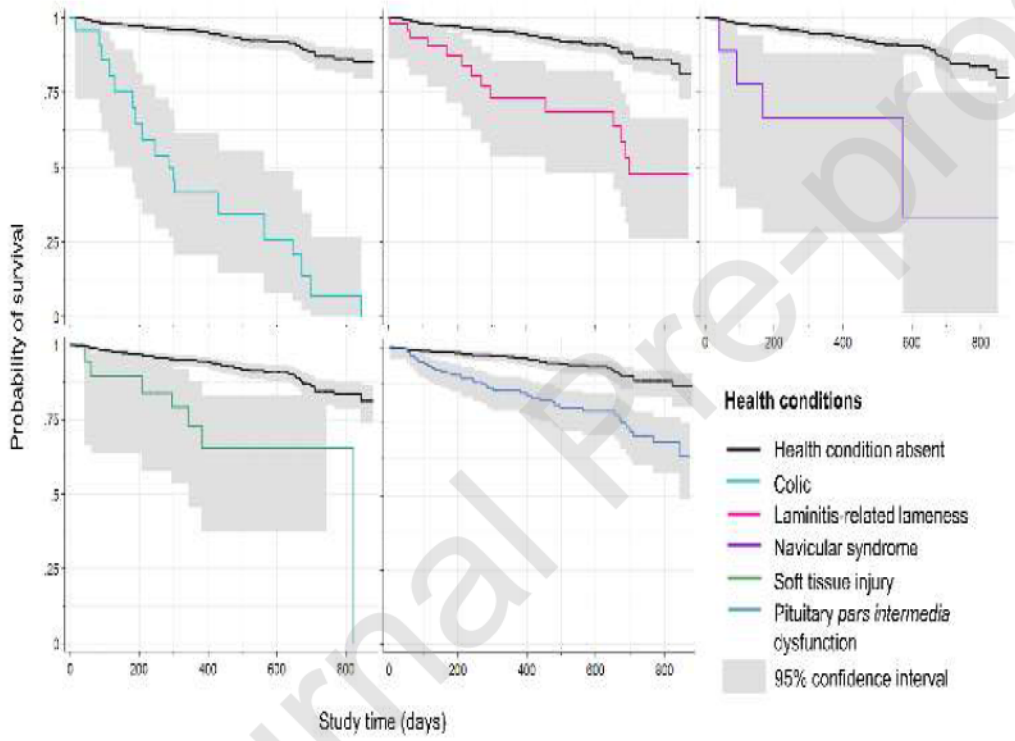
Variable	No. of euthanasias	HYAR /100	Hazard ratio	95% CI	Wald P-value	LRS[#] P-value
Signalment and environment						

Variable	No. of euthanasias	HYAR /100	Hazard ratio	95% CI	Wald P-value	LRS# P-value
Study year						*<0.001*
1 (Aug – Dec 2014)	8	0.6	3.9	1.6, 9.4	0.003	
2 (Jan – Dec 2015)	34	3.5	2.3	1.4, 3.9	0.002	
3 (Jan – Dec 2016)	37	6.8	Ref.			
Type of ownership						*0.02*
Owned by study participant	64	9.3	Ref.			
Loaned/looked after by study participant	15	1.5	2.3	1.2, 4.4	0.02	
Breed category						*0.04*
Cross breed	34	5.6	Ref.			
Pure breed	45	5.2	1.7	1.0, 2.8	0.04	
Sex						*0.03*
Male	40	6.3	Ref.			
Female	39	4.6	1.7	1.0, 2.9	0.03	
Weight tracker use						*0.03*
No	46	5.3	Ref.			
Yes	33	5.5	0.6	0.3, 0.95	0.03	
Health						
Colic in the previous month						*<0.001*
No	61	10.6	Ref.			
Yes	18	0.2	26.4	12.5, 55.8	<0.001	
Pituitary pars intermedia dysfunction						*<0.001*
No	39	8.5	Ref.			
Yes	40	2.3	3.0	1.7, 5.4	<0.001	
Lameness due to navicular syndrome						*0.01*
No	75	10.7	Ref.			
Yes	4	0.1	5.9	1.8, 20.0	0.004	
Lameness due to soft tissue injury						*<0.001*
No	72	10.6	Ref.			
Yes	7	0.2	6.5	2.7, 15.6	<0.001	
Lameness following laminitis episode						*0.01*
Became sound/no previous laminitis	65	10.4	Ref.			
Stayed lame	14	0.5	2.7	1.3, 5.7	0.01	
Hoof care						
Owner-perceived hoof quality						*0.04*
Good/average	69	10.3	Ref.			
Poor	10	0.6	2.4	1.1, 5.2	0.03	
Stabling and turnout						
Turnout routine						*<0.001*
Entirely/partly turned out	69	10.5	Ref.			
Entirely stabled	10	0.3	5.0	2.1, 12.0	<0.001	
Exercise						
Affiliated/professional sport competing						*<0.001*
No	71	10.4	Ref.			
Yes	8	0.4	5.9	2.4, 14.8	<0.001	

[#] Likelihood ratio statistic

Figures

Figure 1 Kaplan-Meier survival plots for horses and ponies (n=1,070) enrolled in a laminitis cohort study in Great Britain, stratified by health conditions found to be significantly associated with euthanasia.



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