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AUTHORS: D Pollard, C E Wylie, J R Newton, K L P Verheyen

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Incidence and clinical signs of owner-reported equine laminitis in a cohort of horses and ponies in Great Britain

Author names and affiliations: D. Pollard[1,3*], C. E. Wylie[2], J. R. Newton[1], K. L. P. Verheyen[3].

[1]Epidemiology Department, Centre for Preventive Medicine, Animal Health Trust, Newmarket, Suffolk, UK

[2]Rossdales Equine Hospital, Exning, Newmarket, UK

[3]Veterinary Epidemiology, Economics and Public Health Group, Pathobiology and Population Sciences, Royal Veterinary College, North Mymms, Hertfordshire, UK.

***Correspondence email**: danica.pollard@aht.org.uk

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Ethical Considerations

This study was granted institutional ethical approval from the Animal Health Trust (AHT01-2014) and the Royal Veterinary College (2014 0105H). Animal use not applicable. Enrolment in the study signified informed owner consent.

Authorship

D.P., C.E.W., J.R.N and K.L.P.V. designed the study. Data collection, analysis and interpretation was conducted by D.P., supervised by C.E.W., J.R.N and K.L.P.V. All authors contributed to the preparation of the manuscript and approved the final version.

Competing Interests

The authors have declared no competing interests. None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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Background: Previous robust epidemiological studies of equine laminitis have utilised only veterinary-diagnosed episodes of disease, potentially underestimating true disease frequency.

Objectives: To estimate the incidence of, and describe clinical signs associated with, owner-reported active laminitis in horses/ponies, using both veterinary-diagnosed and non-veterinary-diagnosed episodes.

Study Design: Prospective cohort.

Methods: Data were collected from horse/pony owners in Great Britain between August 2014 and December 2016 using a web-based application. The incidence of owner-reported laminitis was estimated using both first incident and repeat episodes reported during the study period via a previously-validated laminitis reporting form. Owner-reported clinical signs present in these episodes were recorded.

Results: A total of 1,070 horses/ponies contributed 1,068 horse-years at risk (HYAR) and 123 active laminitis episodes were reported in 97 animals. Sixty-two of these episodes (50.4%, 95% confidence interval [CI] 41.6, 59.2%) were veterinary-diagnosed and 75.3% (CI 66.7, 83.8%; n=73) of horses/ponies reported to have laminitis during the study had a previous laminitis history. Overall owner-reported first episode incidence was 9.6 episodes (CI 7.8, 11.7)/100 HYAR while incidence including repeat episodes was 11.5 episodes (CI 9.7, 13.7)/100 HYAR. Laminitis occurred throughout the year with no significant differences between seasonal incidence estimates. Incidence was highest in Connemara and New Forest and lowest in Draught and Cob breed categories. The most prevalent owner-reported clinical signs (≥70%) were difficulty turning and a short/stilted or lame walk. Laminitis was reported in all limbs however; both forelimbs were most commonly affected (62.9%, CI 54.1, 71.7%; n=73/116).

Main limitations: Self-selection enrolment of participants may limit generalisability of the findings.

Conclusions: Laminitis remains a considerable year-round welfare issue of horses and ponies, with frequency estimates utilising owner-reported data more representative of the true impact of the disease.

The clinical signs reported by horse/pony owners were reflective of those previously described by veterinary surgeons.

Introduction

The variability of laminitis frequency estimates, and the paucity of those applicable to the general equine population, were demonstrated by a systematic review [1]. Veterinary-diagnosed laminitis prevalence estimates within Great Britain (GB) range from 0.5% to 23.5% [2-6]. Differences in study design, populations sampled and laminitis case definitions across studies renders direct comparison between previous laminitis frequency estimates inappropriate [1]. While prevalence presents a simple proportion of diseased individuals in a population, incidence estimates the rate of occurrence of new disease episodes in a population over a specified time period [7]. Incidence rate estimates of laminitis in GB, including well-defined numerator and denominator data obtained via a cohort study approach, are rare. To date, only one prospective cohort study conducted in a veterinary-registered horse/pony population between 2009 and 2011 has estimated that, per year, one in 200 animals registered with the veterinary practices participating in the study were diagnosed with laminitis by a veterinary surgeon (incidence 0.5 per 100 horse-years at risk [HYAR]) [5].

Using only veterinary-diagnosed laminitis episodes in epidemiological studies would likely underestimate disease incidence estimates, with a study of Pony Club animals in Australia indicating that less than 50% of episodes were diagnosed by a veterinary surgeon [8]. Potential for misrecognition of non-veterinary-diagnosed laminitis episodes reported by owners is a valid concern. An initial step, prior to setting up the cohort study, was to conduct an independent cross-sectional study with the explicit aim of determining owners' ability to recognise laminitis and to validate this against a veterinary diagnosis [9]. It was found that all owner-suspected episodes were subsequently confirmed as laminitis by attending veterinary surgeons and that consistency existed between owners and veterinary surgeons when reporting disease-associated clinical signs.

This manuscript arises from a large-scale prospective cohort study which sought to corroborate existing [10], and identify new, potentially-modifiable risk factors associated with owner-reported laminitis development. The aims of the work reported here were to obtain prospective data directly from horse owners to: (i) estimate the incidence of owner-reported active laminitis, (ii) describe and assess

differences in rates between categories of selected non-modifiable exposures and (iii) describe associated owner-reported clinical signs. It was hypothesised that the owner-reported incidence of laminitis would be higher than the previous veterinary-reported estimate, and that owner-reported prevalence of clinical signs would be consistent with previous veterinary reporting.

Material and methods

Study design and period

A prospective, web-based cohort study was conducted in which a sample of self-selected horse and pony owners residing in GB provided regular management and health information on horses/ponies in their care via online questionnaire submissions. For the duration of the recruitment period, the study was advertised at a national level across a variety of equestrian and veterinary media platforms. Owners or full-time carers of horses/ponies residing within England, Scotland or Wales could participate, irrespective of their animal's breed, age, use or previous health status (including laminitis). Owners enrolling only some of their animals were instructed to enrol those whose names appeared first in the alphabet to avoid bias towards animals with previous or existing laminitis. Horses/ponies entered the study on the date a baseline questionnaire (used to gather demographic, management and health data) was submitted for them and exited on the day after their last follow-up submission. Data collection covered a 29-month period, from August 2014 until the end of December 2016. Horses/ponies entered the cohort any time between August 2014 and July 2016 and could exit at any point during the data collection period. Retention of participants was aided by automated monthly reminder e-mails and manual personalised e-mails in instances where follow-ups were not obtained from the participant for more than three months. Study updates were e-mailed to all participants approximately once every two months and regular incentives were used to attract new participants and encourage existing participants to submit follow-ups.

Data collection tools

A 'laminitis reporting form' (LRF) previously used to collect data on clinically apparent veterinary-diagnosed active cases of laminitis in British horses/ponies [5; 9] was modified for owner use in this

study, resulting in an online owner LRF (Supplementary Information Item 1). Owners were asked to report an active laminitis episode in their enrolled animal by submitting a completed LRF which consisted of 10 questions regarding the current active laminitis episode being reported. Tick-box responses (present, absent or not assessed) were collected for 27 clinical signs associated with acute- and chronic-phase laminitis based on lameness, stance, feet affected, and characteristics of the most severely affected foot/feet. Tick-box responses were also collected regarding evaluations (yes, no or don't know) of eight additional factors perceived to be associated with laminitis and which may have provided enhanced confidence in recognition/diagnosis of the present episode. Owners were asked to indicate whether the current episode was veterinary-diagnosed and whether they had previous direct experience with laminitis, either with the same animal or with another horse/pony under their care.

Case definition

A laminitis case was defined as an enrolled horse/pony with veterinary-diagnosed and/or owner-recognised, clinically-apparent, active laminitis, as reported by the owner during the study period [5; 9]. Active episodes of laminitis, both incident and repeat episodes for an individual horse/pony, and of any suspected origin, were included. Animals with a history of chronic laminitis were only included as laminitis cases if they underwent an active episode during the study. Separate LRFs were required for each new, active episode of laminitis. A new episode was defined as 'recognition of active laminitis for the first time or after the horse/pony had returned to its previous level of soundness and activity following a previous episode, without receiving analgesics (e.g. phenylbutazone) for ≥14 days'. An active episode was defined as 'recognition of pain in one/more feet attributed to laminitis, with stance and/or gait abnormalities'.

Data analysis

Initial data cleaning and descriptive analyses were conducted in Microsoft Excel[a] (v.2010). Questionnaires and LRFs were matched by unique owner and animal IDs. Continuous data were described using medians and interquartile ranges (IQR) for non-normally distributed variables and

means with standard deviations for normally distributed variables. Categorical data were described with proportions and 95% confidence intervals (CI).

Owner LRFs were screened and excluded if the horse had only a baseline questionnaire and/or if the episode date preceded the animal's study enrolment. Follow-up questionnaires were screened to determine if any horses/ponies had laminitis during the study, but their owners had not submitted a LRF. Although specific clinical details were missing for these episodes, the date of the episode, whether it was veterinary-diagnosed and recovery period information were available. Data were imported into STATA[b] (IC v.15) for incidence rate calculations.

Incidence: Incidence rate calculations were based on the number of eligible laminitis episodes reported, divided by the total HYAR accrued over the study period. Animals were considered to be at risk of developing laminitis from enrolment until exiting the study, excluding days when they were recovering from an active episode. Overall and category-specific laminitis incidence rates were estimated using both first incident and multiple laminitis episodes reported for each horse/pony. For estimates using only first incident episodes, the date of exit from the cohort for animals with eligible laminitis episodes was the date clinical signs of laminitis were observed. For estimates including multiple episodes, a date of temporary exit from the cohort for animals with eligible active laminitis episodes was the date clinical signs of laminitis were observed. These animals then re-entered the cohort following either an episode-specific or default recovery period. Default recovery periods were estimated using the median time to return to soundness reported at baseline by owners of horses/ponies with a previous history of laminitis. An additional 14-day exclusion period, to account for any analgesic treatment as specified in the case definition, was added to this default median estimate. Where overlap of recovery periods occurred, laminitis episodes were considered recurrences of the initial episode and in these instances, the start of the recovery period was the date of the last recurrence of that episode. Differences in rates between categories of non-modifiable exposures (country of residence, season, breed and laminitis history) were assessed by calculating the point estimate of the difference between rates in each of the 'exposed' categories and the rate in the reference (unexposed) category, along with the CIs [11]. A mid-p

204 significance test was used to derive a two-sided p–value to assess the null hypothesis that the probability
205 of laminitis occurrence in exposed animals was equal to the probability of laminitis occurrence in
206 unexposed animals [12]. Analysis was carried out using the *iri* command and *midp* subcommand in
207 STATA[b] (IC v.15). Significance was set at P≤0.05 with no adjustment for multiple comparisons [13].
208
209 *Clinical signs:* Estimates of owner-reported prevalence and corresponding CI of each reported clinical
210 sign and additional factor were calculated.
211
212 **Results**
213 Longitudinal information was available for 1,070 horses/ponies contributing a total of 1,068 HYAR.
214 Mean owner-reported animal age at baseline was 14.7 years (± 6.9 years) and median animal height
215 was 147.3 cm (IQR 135.9, 157.5 cm). The majority of animals were geldings, belonged to native pony,
216 Welsh and Thoroughbred breed types and resided in England (Table 1). Owners were aware of a
217 previous history of laminitis in 39.1% (CI 36.2, 42.1%, n=418/1,068) of animals.
218
219 Incidence estimates were calculated using 123 laminitis episodes, occurring in 97 horses/ponies (Figure
220 1). A total of 62 (50.4%, CI 41.6, 59.2%) reported episodes were veterinary-diagnosed. The median
221 number of episodes reported per animal was 1 (range 1 to 4 episodes), with 19 horses/ponies having
222 multiple episodes during the study. Of the 97 horses/ponies with laminitis, 73 (75.3%, CI 66.7, 83.8%)
223 had a known previous laminitis history. The 97 animals with reported laminitis during the study were
224 owned by 86 owners, of which 77 (89.5%) had previous direct experience with laminitis.
225
226 *Overall owner-reported incidence rates*
227 Overall owner-reported first episode incidence was 9.6 laminitis episodes per 100 HYAR, based on 97
228 laminitis episodes reported/1,014 horse-years (Table 2). Overall incidence, including repeat episodes,
229 was 11.5 laminitis episodes per 100 HYAR, based on 123 laminitis episodes reported/1,068 horse-years.
230 The median time to return to soundness (obtained from 304 of the 418 horses/ponies reported to have
231 had laminitis previously at baseline) was 30 days (IQR 14, 91 days). Addition of a two-week exclusion

period resulted in 44 days being used as the default recovery period when no episode-specific recovery information was provided.

Incidence rates across categories of non-modifiable exposure

Whilst the laminitis incidence was highest in Wales and lowest in Scotland, rates were not significantly different to England (Table 2). Differences in laminitis rate between winter and the other seasons were not detected (Table 2). Similarly, there were no significant differences between monthly incidence estimates, whether considering first episodes only or including repeat episodes (Figure 2 and Supplementary Information Item 2). December 2016 incidence rates were excluded from the monthly estimates as this was the month the study ended and incomplete denominator data were available for this period.

There was a significant difference in laminitis incidence among breeds, with native pony breeds (excluding Welsh types) having higher incidence rates compared to all other breeds combined, particularly when repeat episodes were considered ($P<0.001$) (Table 2). The incidence was highest in Connemara (first episodes: 24.7/100 HYAR, CI 13.3, 45.8; multiple: 30.4/100 HYAR, CI 18.0, 51.3) and lowest in Cob breed categories (first episodes: 4.1/100 HYAR, CI 1.5, 10.8; multiple: 4.0/100 HYAR, CI 1.5, 10.5) (Figure 3). Incidence was significantly higher in animals with a previous history of laminitis compared to those with no previous reported history ($P<0.001$) (Table 2).

Owner-reported prevalence of clinical signs and additional factors

The owner-reported prevalences of clinical signs associated with gait and stance abnormalities, and with the most severely affected foot/feet, were available for 116 laminitis episodes occuring in 93 horses/ponies (Table 3). The three most prevalent owner-reported clinical signs were ‘difficulty turning’ (77.6%, CI 70.0, 85.2), a ‘short, stilted gait at walk’ (71.6%, CI 63.3, 79.8) and ‘lameness at walk’ (69.8%, CI 61.5, 78.2). While laminitis was reported to occur in all feet across the cases, the majority of episodes affected both front feet (n=73; 62.9%, CI 54.1, 71.7%). The most prevalent additional factor

used by owners associated with confirming laminitis was a previous history of laminitis (n=96, 82.8%, CI 75.9, 89.6) (Table 3).

Discussion

The current study is the first to estimate the incidence of laminitis in a sample of the general horse/pony population of GB using a combination of owner-recognised laminitis episodes that were not attended by a veterinary surgeon and veterinary-diagnosed episodes, whether or not these were recognised by owners. The owner-reported laminitis rate (9.6/100 HYAR) estimated here was considerably higher than the veterinary-diagnosed rate of 0.5/100 HYAR estimated by Wylie *et al.* [5] in a population of veterinary-registered horses/ponies. Due to inherent difficulties with laminitis diagnosis and absence of a 'gold-standard' diagnostic test, the lack of a universally-agreed case definition of laminitis has rendered previous frequency studies largely non-comparable [1; 14]. Data collection tools and case definitions in the current study were derived from the initial cohort study of veterinary-diagnosed laminitis by Wylie *et al.* [5], suggesting the incidence rates estimated in these studies are more comparable than previously-published frequency estimates. Despite this, comparing and further extrapolating estimates between them requires care as recruitment methods, and thus the underlying populations at risk, are likely to fundamentally differ.

In the present study, only half of the owner-reported episodes were also veterinary-diagnosed, indicating that using veterinary-reported information only to validate case selection is likely to underestimate laminitis incidence. Owners were responsible for directly reporting disease episodes for their individual animals, whereas with veterinary reporting the onus was on the veterinary surgeon to submit disease events for multiple animals. Veterinary reporting may have become prohibitive, particularly during times of heavy clinical load, resulting in under-reporting. The denominator population in the present study was well defined, with fewer assumptions made regarding the time at risk each animal contributed to the study in contrast with the practice-based study of veterinary-reported laminitis [5]. The present estimates indicate that on average for every 100 horses/ponies, approximately 10 will develop an incident episode of active laminitis per year. Laminitis, therefore, continues to

present a considerable equine welfare burden, occurring at similar rates to equine health concerns with high welfare impact such as colic [15], the incidence of which has been estimated at 7.2 colic cases/100 HYAR in Thoroughbred horses in GB [16] and 10.6 colic cases/100 HYAR in the US [17]. Current incidence estimates provide a valuable baseline against which future epidemiological studies employing the same validated case definition and data collection tools can be compared, allowing incidence rates to be monitored over time. This becomes particularly important when assessing the impact of recommended intervention strategies aimed at reducing disease incidence.

The current study may have been more appealing to owners with an interest in preventing laminitis due to prior experience with the disease, potentially contributing to elevated laminitis incidence. Almost 40% of owners were aware of a prior laminitis history in their animals and the majority of horses/ponies that developed laminitis during the study (75%) had experienced previous episodes. Thus, most episodes in the present study were not first incident episodes for that individual animal. A study using electronic medical records of 70,481 horses from a UK-based convenience sample of seven first-opinion equine veterinary practices similarly reported that 72% of laminitic horses/ponies developed at least one subsequent episode [18]. The proportions found in the current study are higher than those found in the population sampled by Wylie *et al*. [10], where owners reported that 18% of horses/ponies had a history of laminitis and 49% of laminitis cases in the study had a history of laminitis. The actual recurrence of laminitis probably lies somewhere between these estimates. Whilst the current estimates are representative of the higher end of this spectrum, animals with a laminitis history represent the population on whom the impact of the disease is most evident and for whom future interventions would be of high importance. The study was advertised widely in the equestrian community using conventional and social media via several equestrian organisations, charities, businesses and veterinary practices. While attempts were made to reduce bias based on participants' underlying interests, enrolment was ultimately dependent on an individual's willingness to enrol and engage with data collection.

The owner-reported estimate of when an animal returned to being at risk after recovering from an episode of laminitis was not available for every episode. Default recovery periods were informed by the median time to return to soundness from historical episodes that occurred prior to the study and in the same population of animals. While this is an assumption based on a wide range of owner-reported recovery periods, it was considered to be the best estimate available given lack of existing published data and a relatively arbitrary recovery period used in a previous study [5]. Nineteen animals (19.6%) in the current study had more than one episode while under observation, with five episodes being excluded as they were relapses of an already-reported episode. Adhering to strict case definition criteria and screening the LRFs and questionnaire submissions of each animal further improved the reliability of the incidence estimates.

No significant differences in owner-reported incidence of laminitis were identified between countries within Britain. However, relative to England participant numbers were substantially lower in Wales and Scotland. Greater sample sizes from these countries would have helped in identifying any true differences in laminitis incidence. Peaks in laminitis frequency have been reported previously in spring, summer and winter months [3; 5; 19]. Seasonal variation in temperature, sunshine and rainfall, including milder winters, could be promoting grass growth and proliferation, and in turn contributing to equine obesity and metabolic dysregulation out with traditional seasonal norms. To date, apart from increasing hours of sunshine [3], no other meteorological data related to rainfall or temperature have been significantly associated with laminitis [10]. The current study did not identify statistically significant differences in incidence estimates between winter and other times of the year. The common misconception that laminitis is a predominantly spring-time disease may be contributing to lower vigilance by owners during other times of the year [5]. The results from the present study re-affirm that although there was monthly variation in frequency estimates, laminitis occurred throughout the year and vigilance should be maintained at all times.

The incidence of laminitis in this study population was higher in pony breeds native to the UK and Ireland compared to Cobs and other horse breeds, particularly when multiple episodes were accounted

for. There was an equal proportion of ponies and horses in the present study, whereas other demographic studies have reported horses generally represent 60% of the population [20-22]. This perhaps indicates that pony owners are more motivated to take part in laminitis research as they consider their animals to inherently be at higher risk. Differences in breed predisposition to equine metabolic syndrome and insulin dysregulation have been proposed, which may increase the risk of laminitis in these breeds [23-26]. Current evidence that breed or breed type are significantly associated with laminitis development is inconsistent, indicating that breed alone may not be the most valid laminitis discriminator, particularly without taking into account other health-, management- and exercise-related confounding variables [10; 27]. Breed predisposition to laminitis should be translated to the wider equine community with care, particularly as owners are more likely to recognise laminitis in pony compared to horse breeds [9]. The high incidence of owner-reported laminitis among individuals with a history of laminitis was not a surprising finding, as an owner-reported history of laminitis is a previously-identified laminitis risk factor [10] and potentially also contributed to higher motivation to participate in the current study. Although higher laminitis rates were demonstrated in native pony breeds and animals with a history of laminitis, further robust epidemiological techniques that account for confounding and interaction should be undertaken to confirm the association between these factors and laminitis development.

No individual owner-reported clinical signs were present in every laminitis episode, which is in keeping with previously published findings [5; 14; 28]. The pattern and severity of feet affected was consistent with other studies using veterinary-reported data [5; 14; 29; 30]. Clinical signs most commonly reported by owners in the current study were similar to those previously reported by veterinary surgeons to be most prevalent across 577 laminitis cases [5]. Difficulty turning and a short, stilted or lame walk were reported by owners in ≥70% of the episodes. Thus, the owner-reported episodes in the current study appear to be representative of veterinary-diagnosed episodes. However, the most prevalent clinical sign previously reported by veterinary surgeons, a ‘bounding digital pulse’ [5], was only reported by owners in half of laminitis episodes in the current study and was not assessed in 11% of episodes. Owners more readily reported ‘increased hoof temperature’ as a way of assessing increased digital flow with this being the only clinical sign more commonly reported by owners compared to attending veterinary

surgeons, when both independently assessed the same laminitic horse [9]. Bilateral forelimb lameness, alongside an 'increased digital pulse' were the most useful laminitis discriminators and occurred in 99% of laminitis cases when lame laminitis cases were compared with lame but non-laminitic controls [14]. The typical 'laminitis stance' and divergent growth rings on the hoof capsule were reported by owners in only 18% and 23% of episodes, respectively. Previous studies found both these overt clinical signs to be present in fewer than half of veterinary-diagnosed laminitis cases [5; 9; 14]. Horse carers should, therefore, be made aware of subtle but more prevalent clinical signs which are a better representation of the majority of laminitis episodes [14]. Education regarding the possible spectrum of clinical signs, particularly the location and normal intensity of a digital pulse alongside recognition of lameness, may enhance owner-recognition of laminitis and encourage rapid diagnosis and timely veterinary intervention.

The additional factor most used by owners to help confirm laminitis in their animals was knowledge of a history of laminitis in that horse/pony. It has been well-documented that once a horse/pony develops laminitis, they are at a higher risk of having subsequent episodes [10] potentially due to an accumulated weakening of the lamellar interface following each episode and/or uncontrolled or undiagnosed underlying endocrinopathic disease [31; 32]. The majority of owner-recognised, but not veterinary-diagnosed, episodes were reported by owners with previous direct experience with the disease indicating these owners may be more vigilant and quicker at detecting future disease recurrences [10]. Reliance on owners to recognise laminitis may have led to misclassification of laminitis as another condition in non-veterinary-diagnosed episodes. However, several precautions were taken during the study to minimise misclassification bias. Owners were provided with a clear case definition, data on episodes were collected using standardised, previously-validated data collection tools and the longitudinal nature of the study and regular contact provided ample opportunity for owners to notify the study team regarding changes in their animal's health status [5; 10].

The demographics of the equine population that actively contributed data to the cohort were overall similar to populations described previously [20-22; 33]. A higher proportion of ponies and those with

a previous history of laminitis were identified in the present cohort; however, there is an overall lack of general demographic data regarding the GB equine population. While participants were not blinded to the laminitis-related aims of the study, every effort was made to attract a diverse sample of animals including those with no known history of laminitis. Minimising responder bias in future laminitis cohort studies could potentially be achieved by collecting reporting forms for several common disease outcomes. However, this strategy would also increase logistical and administrative time and cost, potentially resulting in decreased compliance from a less motivated but more diverse population. While the current frequency estimates likely represent the higher end of the laminitis frequency scale in comparison to the veterinary-registered cohort [5], it is likely the true incidence of laminitis in Britain lies somewhere between these two estimates.

Conclusion

The owner-reported laminitis incidence rates estimated in this study are considerably higher than the previously published veterinary-reported rates in Britain. This study highlights that laminitis remains a considerable year-round welfare concern in the British horse and pony population. Additionally, a large proportion of animals experiencing multiple laminitis episodes are not attended by veterinary surgeons and future epidemiological studies of laminitis in Britain would benefit from incorporating data on owner-reported laminitis episodes.

Manufacturer's addresses

[a]Microsoft Corporation, Redmond, Washington, USA.

[b]StataCorp LP, Texas, USA.

421 **Tables**

422 Table 1

423 Demographics of horses and ponies taking part in a laminitis cohort study in Great Britain, presented
424 in descending order of frequency (including 95% confidence intervals [CI]).

Descriptive variable	Frequency	Percentage	Lower 95% CI interval	Upper 95% CI interval
Sex (n=1,070)				
Gelding	615	57.5	54.5	60.4
Mare/filly	448	41.9	38.9	44.8
Stallion/colt	7	0.7	0.2	1.1
Breed categories and their crosses (n=1,070)				
Native ponies	261	24.4	21.8	27.0
Shetland	60	23.0	17.9	28.1
New Forest	57	21.8	16.8	26.9
Connemara	47	18.0	13.3	22.7
Other (including Dartmoor, Exmoor, Dales, Fell, Highland)	84	37.2	31.3	43.0
Welsh	241	22.5	20.0	25.0
Thoroughbred	111	10.4	8.5	12.2
Other horse breed*	96	9.0	7.3	10.7
Other pony breed*	93	8.7	7.0	10.4
Cob	88	8.2	6.6	9.9
Draught	64	6.0	4.6	7.4
Warmblood	60	5.6	4.2	7.0
Arabian	56	5.2	3.9	6.6
Country of residence (n=1,070)				
England	899	84.0	81.8	86.2
Scotland	101	9.4	7.7	11.2
Wales	70	6.5	5.1	8.0
Laminitis history (n=1,068)				
No known previous laminitis	650	60.9	57.9	63.8
Previous laminitis	418	39.1	36.2	42.1

425 *Where a specific breed was not specified, categories of other horse and pony breed groups were made according
426 to height

427

428

429

430 Table 2

431 Overall, country-specific, seasonal and breed laminitis incidence rates per 100 horse-years at risk (HYAR) [including 95% confidence intervals] estimated

432 during the cohort study and in animals with and without a previous history of laminitis, presented using single and multiple episode-per-animal data.

Incidence rate measure	Including single incident episodes only							Including multiple incident episodes						
	Laminitis episodes	HYAR/ 100	Rate/100 HYAR	95% CI	Rate difference[#]	95% CI	P-value[*]	Laminitis episodes	HYAR/ 100	Rate/100 HYAR	95% CI	Rate difference[#]	95% CI	P-value[*]
Overall	97	10.1	9.6	7.8, 11.7				123	10.7	11.5	9.7, 13.7			
Country														
England	85	8.6	9.8	8.0, 12.2	0 (Ref.)			104	9.1	11.5	9.5, 13.9	0 (Ref.)		
Scotland	6	1.0	6.0	2.7, 13.4	-3.8	-9.1, 1.4	0.23	8	1.0	7.7	3.8, 15.3	-3.8	-9.5, 1.9	0.27
Wales	6	0.5	12.0	5.4, 26.8	2.2	-7.7, 12.0	0.61	11	0.6	19.9	11.0, 36.0	8.5	-3.5, 20.4	0.10
Season														
Winter (Dec-Feb)	26	2.7	9.5	6.5, 13.9	0 (Ref.)			30	2.8	10.5	7.4, 15.1	0 (Ref.)		
Spring (Mar-May)	29	2.3	12.5	8.7, 18.0	3.1	-2.8, 8.9	0.30	34	2.4	13.9	9.9, 19.4	3.3	-2.7, 9.3	0.27
Summer (Jun-Aug)	20	2.6	7.8	5.0, 12.1	-1.7	-6.7, 3.3	0.52	28	2.7	10.3	7.1, 15.0	-0.2	-5.6, 5.2	0.94
Autumn (Sep-Nov)	22	2.5	8.7	5.7, 13.2	-0.8	-5.9, 4.4	0.78	31	2.7	11.6	8.1, 16.5	1.0	-4.5, 6.6	0.72
Binary breed category														
Other	61	7.7	8.0	6.2, 10.52	0 (Ref.)			68	8.0	8.5	6.7, 10.8	0 (Ref.)		
Native pony (excluding Welsh)	36	2.5	14.5	10.5, 20.1	6.5	1.4, 11.7	0.006	55	2.7	20.2	15.5, 26.3	11.7	5.9, 17.4	<0.001
Known previous laminitis history														
No	23	6.2	3.7	2.4, 5.6	0 (Ref.)			23	6.2	3.7	2.5, 5.6	0 (Ref.)		
Yes	74	3.9	18.9	15.1, 23.8	15.3	10.7, 19.8	<0.001	100	4.4	22.5	18.5, 27.4	18.8	14.2, 23.5	<0.001

433 [#] The absolute difference in rates between each exposed category and the reference (unexposed) category; [*] Statistical p-value derived from mid-p significance tests of
434 the difference between the probability of laminitis in the exposed and unexposed (reference) groups.
435

436 Table 3

437 Number and prevalence (%) [including 95% confidence intervals] of owner-reported clinical signs
438 associated with equine laminitis, and additional factors considered to have contributed to the current
439 episodes (n=116), during a cohort study in Great Britain, ranked by decreasing prevalence.

Clinical signs	Present n (%)	95% CI (%)	Absent n (%)	95% CI	Not assessed n (%)	95% CI (%)
Difficulty turning	90 (77.6%)	70.0, 85.2	22 (19.0%)	11.8, 26.1	4 (3.4%)	0.1, 6.8
Short stilted gait at walk	83 (71.6%)	63.3, 79.8	30 (25.9%)	17.9, 33.8	3 (2.6%)	0.0, 5.5
Lame at walk	81 (69.8%)	61.5, 78.2	33 (28.4%)	20.2, 36.7	2 (1.7%)	0.0, 4.1
Increased hoof temperature	67 (57.8%)	48.8, 66.7	48 (41.4%)	32.4, 50.3	1 (0.9%)	0.0, 2.5
Reluctance to walk	59 (50.9%)	41.8, 60.0	57 (49.1%)	40.0, 58.2	0 (0.0%)	*
Shifting of weight from leg to leg	59 (50.9%)	41.8, 60.0	57 (49.1%)	40.0, 58.2	0 (0.0%)	*
Bounding digital pulse	59 (50.9%)	41.8, 60.0	44 (37.9%)	29.1, 46.8	13 (11.2%)	5.5, 16.9
Reluctance to lift foot	55 (47.4%)	38.3, 56.5	60 (51.7%)	42.6, 60.8	1 (0.9%)	0.0, 2.5
Lame at trot	52 (44.8%)	35.8, 53.9	18 (15.5%)	8.9, 22.1	46 (39.7%)	30.8, 48.6
Short stilted gait at trot	47 (40.5%)	31.6, 49.5	17 (14.7%)	8.2, 21.1	52 (44.8%)	35.8, 53.9
Pain on sole pressure	40 (34.5%)	25.8, 43.1	62 (53.4%)	44.4, 62.5	14 (12.1%)	6.1, 18.0
Divergent growth rings	27 (23.3%)	15.6, 31.0	74 (63.8%)	55.0, 72.5	15 (12.9%)	6.8, 19.0
Recumbent	23 (19.8%)	12.6, 27.1	92 (79.3%)	71.9, 86.7	1 (0.9%)	0.0, 2.5
Pain on hoof wall pressure	23 (19.8%)	12.6, 27.1	73 (62.9%)	54.1, 71.7	20 (17.2%)	10.4, 24.1
Front feet placed in front of body	21 (18.1%)	11.1, 25.1	95 (81.9%)	74.9, 88.9	0 (0.0%)	*
Widened white line	21 (18.1%)	11.1, 25.1	71 (61.2%)	52.3, 70.1	24 (20.7%)	13.3, 28.1
Refusal to move unless forced	19 (16.4%)	9.6, 23.1	97 (83.6%)	76.9, 90.4	0 (0.0%)	*
Hind feet placed underneath body	19 (16.4%)	9.6, 23.1	96 (82.8%)	75.9, 89.6	1 (0.9%)	0.0, 2.5
Flattened sole	16 (13.8%)	7.5, 20.1	82 (70.7%)	62.4, 79.0	18 (15.5%)	8.9, 22.1
Change in dorsal hoof wall angle	15 (12.9%)	6.8, 19.0	84 (72.4%)	64.3, 80.5	17 (14.7%)	8.2, 21.1
Leg trembling	12 (10.3%)	4.8, 15.9	104 (89.7%)	84.1, 95.2	0 (0.0%)	*
Pink crescent bruising on sole dorsal to frog	10 (8.6%)	3.5, 13.7	92 (79.3%)	71.9, 86.7	14 (12.1%)	6.1, 18.0
Convex sole	7 (6.0%)	1.7, 10.4	92 (79.3%)	71.9, 86.7	17 (14.7%)	8.2, 21.1
Coronary band swelling	5 (4.3%)	0.6, 8.0	104 (89.7%)	84.1, 95.2	7 (6.0%)	1.7, 10.4
Coronary band depression	4 (3.4%)	0.1, 6.8	103 (88.8%)	83.1, 94.5	9 (7.8%)	2.9, 12.6
Hoof wall separation at the coronary band	2 (1.7%)	0.0, 4.1	97 (83.6%)	76.9, 90.4	17 (14.7%)	8.2, 21.1
Sole prolapse	0 (0.0%)	*	108 (93.1%)	88.5, 97.7	8 (6.9%)	2.3, 11.5
Additional factor						

Previous history of laminitis	96 (82.8%)	75.9, 89.6	20 (17.2%)	10.4, 24.1	0 (0.0%)	*
Season/weather conditions	58 (50.0%)	40.9, 59.1	46 (39.7%)	30.8, 48.6	12 (10.3%)	4.8, 15.9
Quality of grazing or pasture available	39 (33.6%)	25.0, 42.2	68 (58.6%)	49.7, 67.6	9 (7.8%)	2.9, 12.6
Overweight body condition	37 (31.9%)	23.4, 40.4	74 (63.8%)	55.0, 72.5	5 (4.3%)	0.6, 8.0
Breed type	35 (30.2%)	21.8, 38.5	63 (54.3%)	45.2, 63.4	18 (15.5%)	8.9, 22.1
Age	33 (28.4%)	20.2, 36.7	70 (60.3%)	51.4, 69.2	13 (11.2%)	5.5, 16.9
Accidental carbohydrate/concentrates overload	9 (7.8%)	2.9, 12.6	105 (90.5%)	85.2, 95.8	2 (1.7%)	0.0, 4.1
Underweight body condition	2 (1.7%)	0.0, 4.1	109 (94.0%)	89.6, 98.3	5 (4.3%)	0.6, 8.0

*Not calculable as zero in cell

Figures

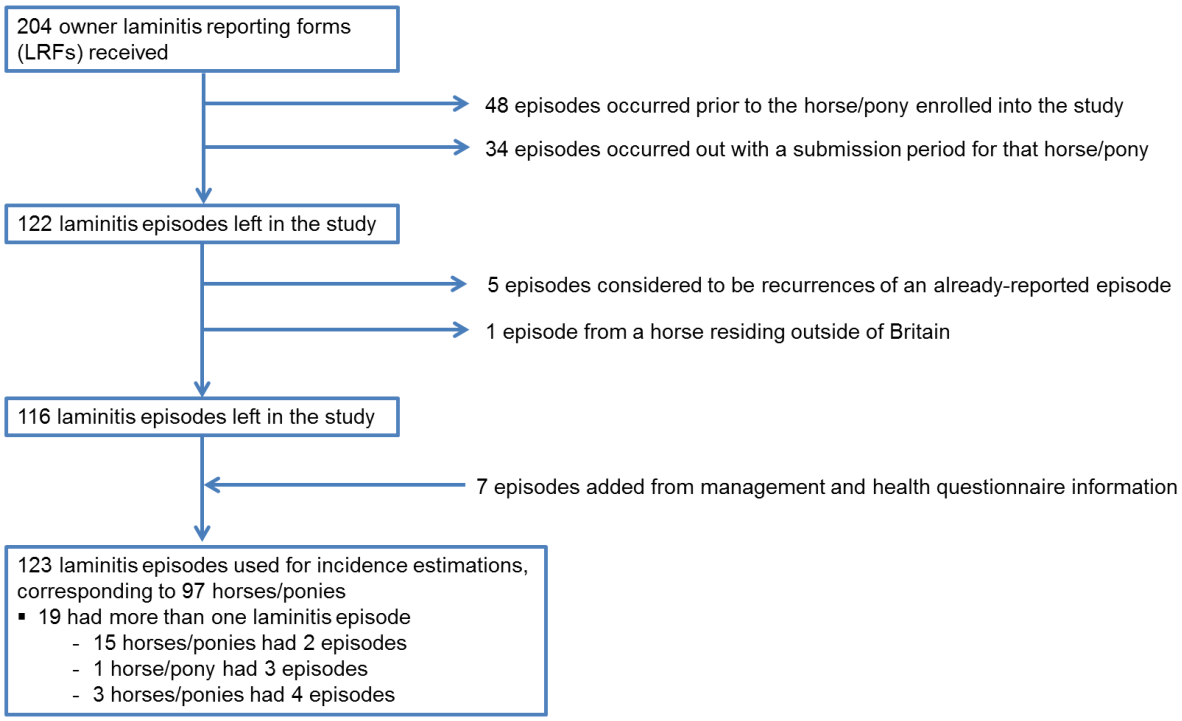
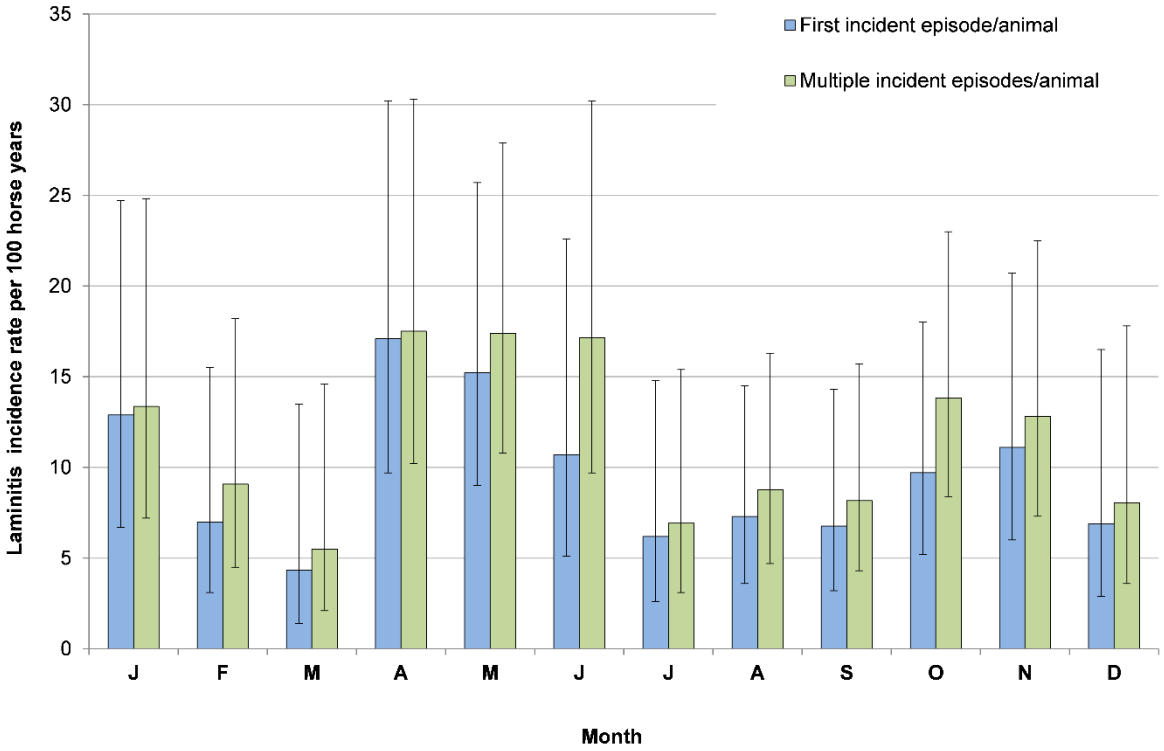


Figure 1: Flow diagram showing the screening of owner-reported laminitis episodes for inclusion in the cohort study incidence estimates in a study of equine laminitis in Great Britain between August 2014 and December 2016.



450

451 Figure 2: Combined monthly incidence of owner-reported laminitis in a cohort of 1,070 horses/ponies
452 in Great Britain, summed over matching study period months. Error bars represent 95% confidence
453 intervals.

454

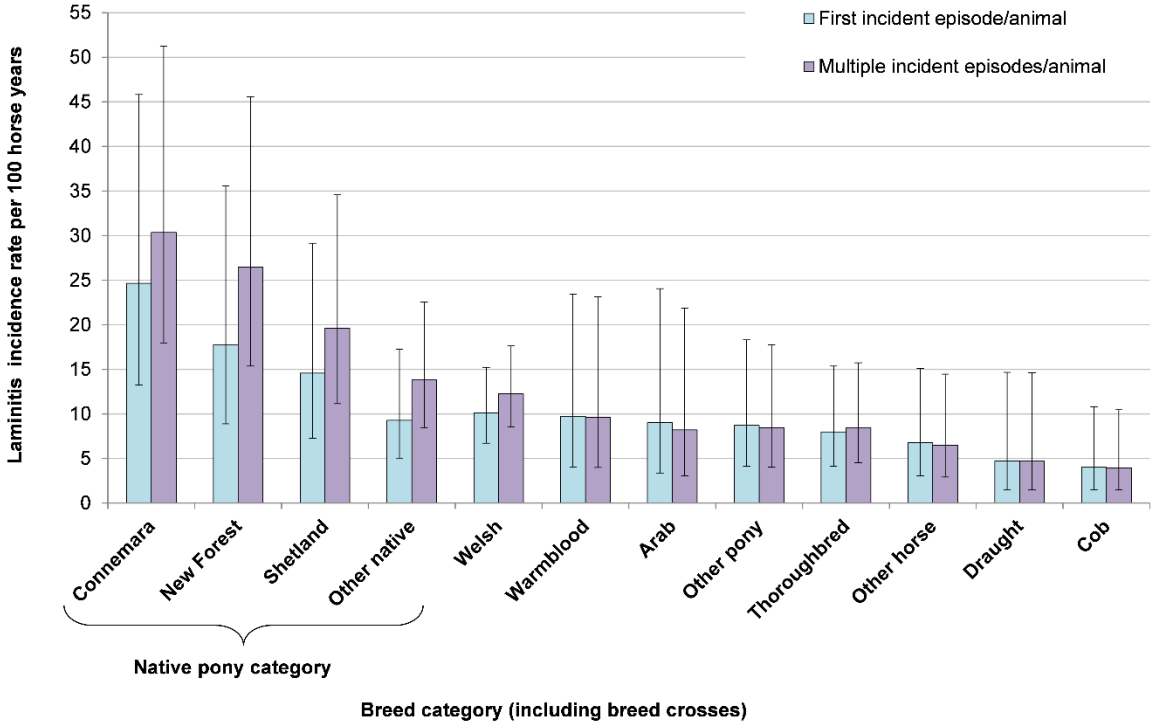


Figure 3: The breed category laminitis incidence in a cohort of 1,070 horses/ponies in Great Britain between August 2014 and December 2016. Error bars represent 95% confidence intervals.

Supplementary information

Item 1: Online owner laminitis reporting form used to collect data on active laminitis episodes in a prospective cohort study of laminitis in Great Britain between August 2014 and December 2016.

Item 2: Figure 3: Incidence of owner-reported laminitis in a cohort of horses/ponies in Great Britain, for each individual month of the study period. Error bars represent 95% confidence intervals.

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