A clinical survey study of the recognition and impact of equine lameness on the Great British horse owning population

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1 Overview

Despite the generally perceived importance of equine lameness as a significant cause of morbidity and wastage amongst the worldwide horse population, little is known about the prevalence and impact of equine lameness on the UK horse and owner population. Likewise, little is documented on how lameness is detected and assessed by horse owners. Information regarding perception of equine lameness by the untrained assessor is potentially valuable to the equine orthopaedic clinician. Improved awareness of owners' appreciation of lameness, as well as the impact an episode of lameness may have would be of benefit to all parties; the veterinary surgeon, the horse owner and the horse.

1.1 Background and aims of the studies presented in this Thesis

1.1.1 Survey Study

The impact of equine lameness on both the horse and owner was investigated to identify and quantify the basic cost of horse ownership. By knowing what the baseline cost is for daily maintenance of a horse, we can better understand the cost of temporary restricted use of the horse from doing the activities the owner desires. The number of days out of work is a hidden cost of equine lameness, which is rarely taken into account when an owner presents their horse to a veterinary surgeon for orthopaedic assessment.

An online survey study was designed to obtain both descriptive and quantitative information on the UK horse population; the prevalence of equine lameness as reported by the owner; and the effect that a single episode of lameness may have on both the horse and owner.

1.1.2 Lameness Study

Lameness assessment in itself is highly variable amongst examiners and appears to be highly dependent on level of training and experience, both for reliability on a single orthopaedic examination and on repeated examinations. With increasing pressure to practice evidence based medicine, methods of objective lameness detection have been developed in clinical research which can reliably quantify normal and abnormal gait in the horse (Ross & Kaneene 1996).

A prospective hospital- based study was designed to investigate reasons for referral and owners' general assessment of lameness prior to veterinary examination; to quantify and compare lameness severity using subjective and objective methods of assessment; and to determine the areas of best agreement between subjective evaluation (owner; veterinary surgeon) and objective evaluation (Lameness Locator ®)[1].

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[1] Equinosis
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5 Acknowledgement

I would like to thank my supervisor Dr. John Marshall for giving me the opportunity to undertake the challenge of a combined surgical residency and MVM programme. Through this Masters project, I have been awarded the opportunity to present the findings at local, national and international conferences, which has significantly developed my abilities and confidence as a researcher. I would like to gratefully acknowledge The Geoffrey Serth Charitable Trust for funding this research and my surgical residency programme through The Horse Trust.

I am very grateful for the assistance of the public who took the time to participate in the research. The survey studies were piloted on my wonderful colleagues and co- workers at The Weipers Centre Equine Hospital, who also played an important role in data collection during the lameness assessments.

The support and motivation from my close friends and family, in particular Alexandra Raftery, Mark Salji, Susan Armstrong, Antonia Bomba and Alannah Norton has been much appreciated throughout the entire Masters programme. A special mention also goes to Dr. Lisa Boden for the statistical analyses and in- depth advice given throughout the planning, analysis and writing stages of the research.

6 Author’s declaration

I declare that, except where explicit reference is made to the work of others, that this thesis is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution. The entire work is an original study. Where data has been submitted to a scientific journal, it has been clearly stated at the beginning of the chapter.

All data were collected with client informed consent. The studies undertaken as part of this thesis were granted approval by the University of Glasgow Veterinary School Animal Ethics and Welfare Committee.

Signature:

Printed name:

7 Definitions/ abbreviations

AAEP- American Association of Equine Practitioners

ALD- Angular limb deformity

BETA- British Equine Trade Association

CPS- Cumulative pain scale

FLD- Flexural limb deformity

HDMax- The mean difference in millimetres in maximum head height after the stance phases of the right and left forelimb

HDMin- The mean difference in millimetres in minimum head height during the stance phases of the right and left forelimb

IQR- Interquartile range

LL- Lameness Locator®

NEHS- National Equine Health Survey

NRS- Numeric rating scale

OCD- Osteochondrosis Dessicans

PDMax- The mean difference in millimetres in maximum pelvic height after the stance phases of the right and left hindlimb

PDMin- The mean difference in millimetres in minimum pelvic height during the stance phases of the right and left hindlimb

VAS- Visual analogue scale

VRS- Verbal rating scale

VS- Vector sum

8 Chapter one: A review of the UK horse population and the prevalence of equine lameness

8.1 UK horse population

An industry poll estimated that there are approximately 944,000 privately owned horses in the UK, used predominantly for unaffiliated competition and 'general purpose' riding. In the UK, there are estimated to be 446,000 horse- owning households comprising 2.7million horse riders (BETA 2015). The market value of total sales of horse-related goods and services produced in Great Britain had an estimated annual gross ouput of £3.4 billion in 2005 (British Horse Industry Confederation 2005). The estimate of total horse population is certainly inaccurate, however does correlate with previous estimates by BETA (1999) and that suggested by Mellor and others in a study of demographic characteristics of the equine population of northern Britain (Mellor et al. 1999).

8.2 Prevalence of equine lameness

Despite major advances in veterinary medicine to diagnose and treat lameness related injuries in the last 30 years, there is little change associated with the implicated costs and welfare of both pleasure and performance animals (Jeffcott et al. 1982; Dyson et al. 2008; Egenvall et al. 2009). Lameness is generally accepted as a significant cause of decreased productivity and consequently wastage in horses and ponies across all equine industries. For the UK, estimations of horses affected by lameness range from 11% (Slater 2015) in privately owned horses to 20% of Thoroughbreds affected by lameness which is sufficient to prevent an individual from racing post-injury (Dyson et al. 2008). A practice- based survey of horses in Northern Britain identified that owners ranked lameness as the most important disease and the commonest cause of permanent or recurrent disease in horses (Mellor et al. 2001).

The National Equine Health Survey (Slater 2015) is an annual UK- based study which collates equine demographic and healthcare information. The survey is run by the Blue Cross charity, carried out on a convenience sample of horse owners and is heavily advertised by many large companies and share- holders in the equine products market so that as many horse owners are exposed to the survey. The findings are collated and published online for horse owners and those working within the equine industry to learn about our current equine population and trends in common problems such as obesity, lameness and other causes of morbidity. The survey is web-based and is conducted over a one week period on an annual basis. The latest survey published in August 2015 reported lameness not related to the foot (degenerative joint disease/ osteoarthritis) has a prevalence of 13.5%, and foot lameness a prevalence of 4.5%. In comparison to previous years, there has been no change in reported numbers of foot lameness and a decrease from approximately 18% in 2013/ 14 in prevalence of limb lameness. This survey does not provide any information on owner expenditure or loss of use of a horse during an episode of lameness.

Limb lameness problems of the hoof or foot have been the most frequently observed groups of health problems in multiple large cross- sectional survey studies worldwide (Kaneene et al. 1997; Cole et al. 2005; Ireland et al. 2012). Prevalence of equine lameness in non- racing horses ranges from 29.6% in an Australian population (Cole et al. 2005) to 65.8% of geriatric (>15 years old) horses in the UK (Ireland et al. 2012) over a 12 month period. In 1997, a large prospective study was designed to document the frequencies of equine health problems in the state of Michigan, USA (Kaneene et al. 1997). Measure of annual incidence identified that leg lameness was the most frequent health problem, with foot and hoof problems ranked fourth most frequent. The National Health Monitoring Service in the USA estimated the cost of lameness to be from $678 million to $1 billion in 1998 with 66% of costs associated with loss of use of horses and 29% of costs attributed to veterinary services, drugs and additional care costs (Seitzinger & Traub-Dargatz 2000).

Lameness has been reported in the Thoroughbred racing industry as the main cause of lost training days (Hernandez & Hawkins 2001; Dyson et al. 2008), the economic impact of which can be quantified using training fees, lost revenue and number of days out of training (Hernandez & Hawkins 2001). Currently, there are no specific UK- based lameness prevalence studies for non- racing Thoroughbred horses and therefore prevalence of lameness is variable due to the alternative focus of the current published data (geriatric horse healthcare, specific health disorders e.g. laminitis). These reports are useful and provide an insight into the prevalence of lameness in different subsets of horses, however the horse population is likely to be biased towards those populations predisposed to lameness (older, concurrent chronic illness). When the impact of disease was evaluated in terms of average duration of a case and lost days for performance (Kaneene et al. 1997), lameness had the overall highest annual incidence density. It was also reported as the disease with the second highest duration and performance days lost, and was again, ranked first in perceived importance by horse owners and farm managers.

Treatment of equine lameness frequently requires a period of rest or restricted exercise. The financial impact of restricted use should be considered when making further investigation and treatment decisions. To the author's knowledge, no studies on the impact of equine lameness on the owner have been carried out in the UK. The financial outlay associated with a single episode of lameness is currently unknown in the privately owned UK horse population. Given that this subset of the equine population occupies the majority of the horses in the UK, it seems there is a dearth of information available on the cost of routine care and the basic financial impact of inactivity on the horse owner. The cost of an episode of lameness is quantified by a veterinary surgeon's intervention and the cost of restricted use of a horse is not frequently identified as a significant cost (Seitzinger & Traub-Dargatz 2000), in comparison with production animals (Green et al. 2002; Jensen et al. 2012) where the effects of lameness are more easily quantified.

9 Chapter two: An online survey to characterise spending patterns of horse owners and to quantify the impact of equine lameness on a pleasure horse population.

A version of this chapter has been submitted as a manuscript to The Veterinary Record for publication. The manuscript is currently under review. Some of the figures and tables are included in the submission but all captions have been altered according to plagiarism rules.

9.1 Aims and objectives

The aims of this study were to describe and quantify the daily cost associated with horse maintenance including routine healthcare and to quantify the financial impact and time outlay associated with the loss of use of a horse for its desired purpose during a single episode of lameness. By calculating the basic daily cost of ownership, the cost of inactivity during a period of rest or rehabilitation can be approximated. We hypothesized that the daily cost of ownership would be influenced by geographical horse location, and would increase in cases where horses were i) kept in full time livery; and ii) were used for competition purposes.

9.2 Methods

9.2.1 Online questionnaire

A national study of UK mainland horses was initiated in July 2013 and conducted until December 2013. The questionnaire contained 35 open and closed questions of which 25 ‘essential questions’ had to be completed in order to progress to the next question. Of the nineteen closed questions, ten had an ‘other’ option where respondents could add information in an unstructured text based format. The study was split into four individual sections to describe i) the respondent population; ii) the horse population; iii) the cost of ownership; and iv) the occurrence of a single episode of lameness within the previous 12 months. The questions related to the age, gender and location of owner in relation to their horse, the type and use of horse, purchase price, location, travel, and the cost of routine healthcare and general maintenance. Survey participants were given instructions that only one member of a household should complete the questionnaire and the horse-related answers should be based on a single horse. Assuming respondents were binomially distributed with the worst-case scenario in which 50% of all respondents give the same response to each question, a minimum of 100 respondents for each question was required, to be confident in our estimates +/- 10%. This is derived using a normal approximation to the binomial.

9.2.2 Pilot Study

Before the online questionnaire was launched to the public, it was piloted amongst a population of 13 horse owners within the University of Glasgow. Respondents were asked to mark words or questions which had an unclear meaning. They were asked to critique the layout of the questionnaire, the number of questions, the style and level of difficulty of the questions and the overall length of the questionnaire. The questionnaire was refined in response to this exercise and the results from this pilot study were excluded from the analysis. Based on the pilot study, respondents were informed that the survey would take approximately 15 minutes to complete, and were informed of the study objectives in the format of a simple introductory paragraph. A hard copy of the final questionnaire is available in appendix 13.1.2.

9.2.3 Respondent recruitment

An online link to the survey was made available to the public through a series of online platforms advertising an online link to the survey. Survey respondents thus formed a convenience sample of horse- owners who volunteered to participate in the study by completion and submission of the questionnaire. The respondents remained anonymous and were advised that details would not be passed on to any third parties. The link to the online survey was publicised through equestrian media and social media (via both broadly accessed systems such as Facebook and Twitter as well as more equine- specific webpages). Prior to release of the survey, local and national equine companies and organisations were contacted via email with a letter of introduction describing the background and aims of the study (appendix 13.1.1). This group were asked to circulate the survey link amongst their own email contacts and publicise the link on web sites, Twitter feeds and Facebook pages. The Equine-specific web pages included Horse &

Hound, British Eventing, British Dressage and British Show Jumping. Questionnaires were completed in English using an online survey provider ('Survey Monkey')[2].

9.2.4 Survey respondents

The unit of observation was the questionnaire respondent (horse owner or primary horse carer). In this study, the term 'horse' refers to horses and ponies. Respondents who responded later than December 2013 were not included in this dataset for analysis. Respondents were excluded from the study if no county or postcode were supplied, if either of these were outwith the UK or were found to be incorrect. Respondents were also excluded if the study was not completed beyond the first of four sections. As the study was split into four sections, each section was individually analysed therefore respondents could be included in a minimum of two sections and a maximum of four sections provided the essential information was available.

9.2.5 Survey responses

Data on excluded respondents was recorded with the aim of being able to determine the 'drop-out rate' after each section of the questionnaire and for each individual question. To determine reliability of the responses a 'repeater question' was included within the first five questions and again within the final 10 questions. To establish good compliance for respondents to complete the entire survey based on a single animal, the horse's name was requested in question 9. The horse's name was then nested into twenty- six of the remaining questions.

The daily cost of horse ownership was estimated using the values submitted for the cost of basic feeding, stabling and routine healthcare including annual vaccination, worming, farriery and dentistry. The daily cost of the entire respondent population was examined further using geographical location; type of stabling facility and use of horse as variables to more accurately describe the differing costs of temporary loss of use. The survey methodology was evaluated using the overall response rates, the drop out rates and the agreement between the repeater questions at the beginning and end of the series of questions.

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[2] www.surveymonkey.com

9.2.6 Geographical representation

The geographical distribution of horses was described at postcode, county and region levels (East England (EE), East Midlands (EM), West Midlands (WM), North East England (NE), North West England (NW), Yorkshire and Humber (YH), Greater London (GL), South East England (SE) and South West England (SW), Northern Ireland (NI), Wales (W), and Scotland (S). Regions within England were based on those defined by the Office of National Statistics (http://www.ons.gov.uk/ons). The spatial distributions of the questionnaire datasets were displayed to show the concentration and distribution of respondents.

9.2.7 Data Analysis

Data distribution was tested using the Shapiro-Wilk test and descriptive statistics were produced for all data based on distribution. The survey validity and reliability was evaluated using the overall response rates, the drop- out rates and the agreement between the repeater questions at the beginning and end of the series of questions. Those respondents who did not fully complete Section 3, but had completed the first 2 sections were classified as 'late non- responders'. Although non-responder bias cannot be formally assessed from an online questionnaire, a binary variable coding for individual participation in the study was created (i.e. those respondents who completed only sections 1 and 2 were termed 'late non- responders') to investigate differences between the late non- responders and those who completed the entire survey. Data on excluded questionnaire respondents was investigated to assess survey reliability and whether selection bias was present. This was done by comparison of variables (postcode region, respondent age) for included and excluded respondents using chi-squared tests for categorical data. Individuals who responded only to the first two sections of the survey were considered to be similar to non-respondents.

9.3 Results

9.3.1 Pilot Study

Descriptive written feedback was acquired from the 13 pilot responders who remained anonymous to the author. All respondents were owners and riders of at least one horse, and were between 20 and 50 years of age. The overall feedback was positive with regards to the questionnaire design and layout. The pilot respondents felt the original title ‘An epidemiological study on the costs associated with equine ownership and lameness’ was too complicated and therefore was simplified to ‘The impact of equine lameness on horses and owners in the UK and Ireland’. In addition, one question was removed completely regarding the number of days per year an owner may pay for someone else to care for their horse. This question was initially deemed important for its contribution to the baseline cost of ownership, however after negative feedback due to being a cause of confusion we considered it a cost, which would have minimal impact on the final calculations.

9.3.2 Respondents

After exclusion of minimally completed questionnaires there were a total of 551 respondents. The respondents’ postcode identified the geographical location of the owner, which was further categorised into UK regions (Figure 1). The 3 highest populations of equine owners were recorded in the South- East of England, Scotland, and the South- West of England (20%, 112/551; 17%, 91/ 551; 15%, 81/551 respectively). The majority of equine owners were female (98%, 541/551) and age distribution was spread equally between 16- 54 year olds with each 10-year age bracket being representative of approximately 20% of the population. A third of respondents (30%, 165/551) owned/were responsible for a single horse, and an additional 58% (320/551) for 2-4 horses. The remaining population of respondents were responsible for greater than 5 horses. Eighty- five per cent of the population (470/550) described themselves as horse owners that ride. Basic time expenditure per week was recorded categorically and identified that 73% (396/546) of the respondents spent 5- 20 hours per week with their horse. More than 20 hours per week was recorded for 22% (121/546) of the population. The majority of horses were kept within 5 miles of the owners place of residence (49%, 268/ 549), or on owner’s own premises (29%, 158/549). This information was obtained in the first of four sections of the survey (Table 1).

Region	Number respondents	% of survey population	95% CI (%)
SE	112	20	17-24
S	91	17	14-20
SW	81	15	12-18
WM	51	9	7-12
YH	45	8	6-11
EE	40	7	5-10
NW	35	6	4-9
W	27	5	3-7
EM	24	4	3-6
NE	20	4	2-6
L	16	3	2-5
NI	7	1	0.5-3

Figure 1: A UK map and table to show the density and distribution of respondents within each region of the UK, according to postcode. The mapped- numbers reflect the distribution of respondents by region as a percentage of the total number of survey respondents

Survey section 1- Horse owner descriptive data			
Owner Sex	**Number respondents**	**%**	**95% CI**
Male	10	2	0.9-3
Female	541	98	97-99
Owner Age (years)			
Under 16 years old	9	2	0.9-3
16 to 24 years old	132	24	20-28
25-34 years old	141	26	22-29
35 to 44 years old	104	19	16-22
45 to 54 years old	106	19	16-23
55 years or older	59	11	8-14
Number of horses			
1 horse	165	30	26- 34
2-4 horses	320	58	54-62
5-10 horses	43	8	6-10
Greater than 10 horses	20	4	2-6
Other	3	1	0.1-2
Involvement			
Horse owner that rides	470	85	82- 88
Horse owner that does not ride	20	4	2-6
Loaner/ rider but not owner	22	4	3-6
Other	38	7	5-9
Time spent per week (hours)			
Less than 1 hour	2	0	0.04-1
1-4 hours	27	5	3-7
5-10 hours	158	29	25-33
11-20 hours	238	44	39-48
Over 20 hours	121	22	19-26
Horse location			
On premises	158	29	25-33
5 miles or less	268	49	45-53
Between 5 and 10 miles	90	16	13-20
Between 11 and 50 miles	32	6	4-8
Over 50 miles	1	0	0-1

Table 1: A table to show the descriptive data for the owner population of survey respondents

9.3.3 Horses

The population of horses in this study (n=551) represented a mixture of breeds (Figure 2) and ages (median age of 13 years, IQR 9-16 years, range 2-34 years). The population included 345 geldings (62.6%), 204 mares (37%) and 2 entire males (0.4%). The majority of horses were kept on livery yards (50%, 274/549) or on a yard not situated at the owners' home (31%, 173/549). A smaller proportion of horses were kept at the owners home (19%, 102/549). Purchase price was recorded categorically which showed that the majority of respondents (39%, 214/549) had paid between £2001 and £5000 for their horse (Table 2). Forty- seven per cent (256/547) of horses had undergone a pre-purchase examination and 64% (349/549) of the population were insured following purchase (Table 2). A total of 483 horses were used for general purpose riding. Of these, 62% (303/ 483) competed in affiliated or unaffiliated events and 38% (183/ 483) were used for hacking purposes only. The non- ridden horses were either retired, used for breeding purposes or other activities such as trotting racing, carriage riding or groundwork and natural horsemanship. The competition horses were further divided to identify those who competed at high (affiliated) versus low (unaffiliated) level competition within the population. Forty- five per cent (136/300) competed at affiliated events whilst 55% (164/ 300) competed at unaffiliated events.

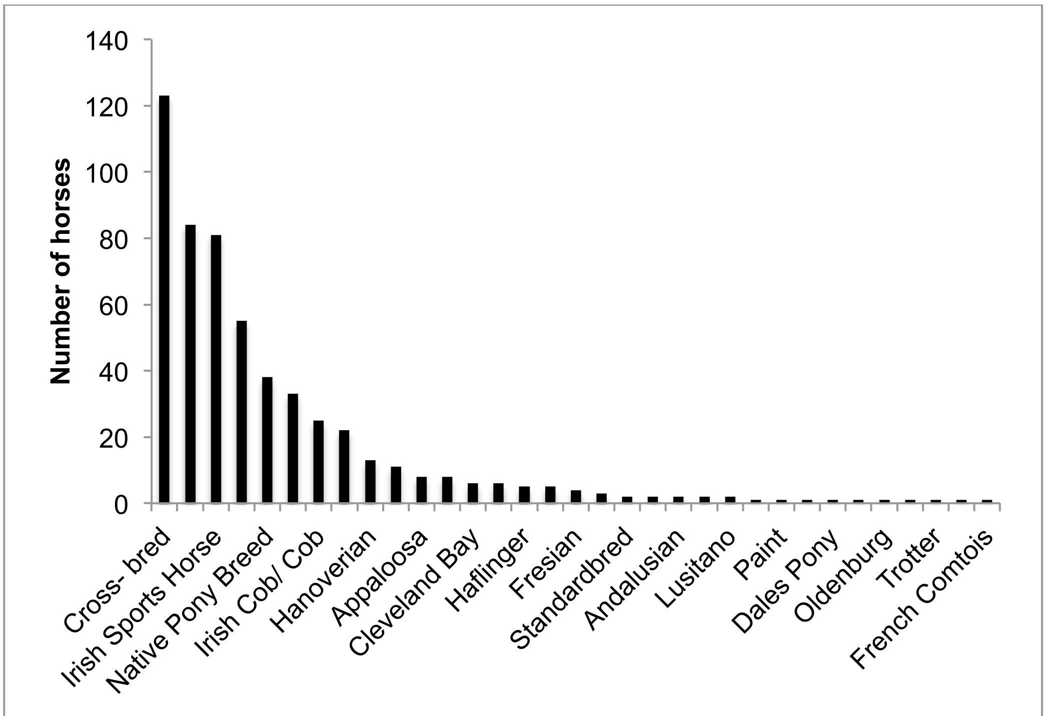


Figure 2: A graph to show the range and distribution of horse breeds included in the survey responses

Survey section 2- Horse descriptive data			
Horse Sex	**Number respondents**	**%**	**95% CI**
Entire male	2	0.4	0.04-1
Gelding	345	62.6	58-67
Female	204	37.0	33-41
Stabling type			
On a yard at home	102	19	15-22
On a yard elsewhere	173	31	28-36
Full livery (incl. exercise)	12	2	1-4
Part livery (excl. exercise)	61	11	9-14
DIY livery	201	37	33-41
Purchase cost (£)			
Less than 500	56	10	8-13
501- 1000	48	9	7-11
1001-2000	102	19	15-22
2001-5000	214	39	35-43
5001- 10,000	66	12	9-15
More than 10, 000	15	3	2-4
Other	48	9	7-11
Level of use			
Non- competition	183	38	34-42
Affiliated competition	136	28	24-32
Non- affiliated competition	164	34	30-38
PPE			
Yes	256	47	43-51
No	291	53	50-57
Insurance			
Yes	349	64	59-68
No	200	36	32-41

Table 2: A table to show descriptive data for the horse population according to the survey respondents

Feed Supplements	Number respondents	%	95% CI
Yes	370	77	73-81
No	109	23	19-27
Supplement Type			
None	110	23	19-27
Joint	83	17	14-21
Garlic	59	12	10-16
Hoof	41	9	6-11
Calmer	31	7	4-9
Electrolyte	28	6	4-8
Herbal anti- inflammatory	19	4	2-6
Cod liver oil	10	2	1-4
>2 of above	44	9	7-12
Other	54	11	9-14
Physiotherapy			
Yes	184	42	38-47
No	252	58	53-62
Alternative therapies			
Yes	85	20	16-24
No	349	80	76-84
Alternative therapy type			
Osteopathy/ chiropractic	29	34	24-45
Massage	23	27	18-38
Reiki	8	9	4-18
Acupuncture	5	6	2-13
Bowen Therapy	5	6	2-13
Homeopathy	3	4	0.7-10
Aromatherapy	3	4	0.7-10
Magnetic	3	4	0.7-10
Other	6	7	3-15

Table 3: A table to show the use of feed supplements and alternative therapies within the horse population, according to the survey respondents

9.3.4 Basic maintenance costs

To quantify the cost of keeping a horse the sum of stabling, feed and routine care (vaccinations, worming, farriery and dentistry) was calculated per owner to form a total annual expenditure. Only owners who had a complete dataset were included for this analysis (total 482 respondents). The overall median cost was £2060 per year, equivalent to £5.64 per day ranging from an average of £886 for those who kept their horse on a yard at home to £5848 for those kept in full time livery. Annual vaccination information had a median cost of £50 (25th percentile £30, 75th percentile £70, maximum spend £300). Anthelmintic treatment in this survey included but did not distinguish between the cost of faecal egg counts and anthelmintic treatments and the median annual cost was £45. The cost of dentistry and farriery were requested as an annual figure due to differing procedure intervals, for which the median annual expenditures were £45 and £400 respectively (Table 4).

Survey section 3- Cost of ownership				
Routine healthcare	**Median Annual Cost (£)**	**Min**	**25th-75th Percentile**	**Max**
Stabling	1440	0	540-2400	8400
Feed	80	0	40-140	2020
Vaccinations	50	0	35-70	471
Worming	45	0	30-60	475
Dentistry	45	0	35-65	1900
Farriery	400	0	220-600	1600
	Total: £2060			
Additional costs				
Feed supplements	240	9	120-360	1800
Competition	100	6	50-300	5000
Competition travel	150	4.5	60-300	4500
Lessons	300	20	150-600	1500
Lesson travel	100	10	50-200	1000
Physiotherapy	100	20	60-200	1000
Alternative Therapies	100	10	50-100	1270
	Total: £1090			

Table 4: A table to summarise the basic and additional costs of horse ownership

Daily costs of horse maintenance were also investigated according to the factors suspected to affect the daily cost of ownership. Keeping a horse in full livery versus own premises contributed most towards the overall cost of keeping a horse at four times the daily cost (£16.50 versus £4.10 respectively). Other variables that increased the maintenance costs included horse insurance; use of the horse for competition purposes, and the region of the UK where the horse was stabled (Table 5).

Region	Median cost per year (£)	Median cost per day (£)	Min	25th-75th Percentile	Max
London	3790	10.4	582	2426- 4660	5689
Northern Ireland	2860	7.8	1560	2334- 3930	5579
West Midlands	2735	7.5	349	1478- 3980	9230
East of England	2523	6.9	229	1474- 3049	7751
North West	2476	6.8	780	1314- 3180	5585
North East	2413	6.6	191	1352- 3426	5340
South East	2150	5.9	60	1348- 3342	9348
South West	2140	5.9	188	1110- 2715	8440
York and Humber	2043	5.6	130	1150- 2783	9530
East Midlands	1979	5.4	295	1515- 3211	6790
Scotland	1703	4.7	188	817- 2859	8070
Wales	1548	4.2	85	959- 2666	8235
Horse Kept					
Yard at home	1208	3.3	60	715- 2109	9230
Yard elsewhere	1506	4.1	130	817- 2593	9348
Full livery	5630	15.4	1830	3600- 7595	9530
Part livery	4660	12.8	698	3344- 5860	8440
DIY livery	2476	6.8	188	1849- 3237	5890
Use of horse					
Competition	2400	6.6	130	1345- 3593	9348
Non- competition	1824	5.0	60	892- 2755	9530

Table 5: A table to summarise the factors influencing the basic maintenance cost of horse ownership (not including additional costs as detailed above)

9.3.5 Additional costs

Additional costs included insurance, travel, competition fees, the use of a physiotherapist and other alternative therapies, and the use of feed supplements (Tables 3 and 4). Feed supplements were fed to 77% of the population of horses (370/479). The most common supplements were joint supplements (17%, 83/369) followed by garlic, hoof supplement, calmer, and electrolytes. Herbal anti- inflammatory (4%, 19/369) was most commonly given in combination with a joint supplement. In addition, a further 9% (44/ 369) fed more than two of the listed supplements. The remaining respondents were those who fed mixed herbs, gastric supplement and cod liver oil (13%, 64/369), categorised as ‘other’. There were a total of 269 respondents who used methods of alternative therapy for their horse. Physiotherapy accounted for 68% of respondents (184/ 269), and other alternative therapies were used in 85 horses. Excluding physiotherapy, chiropractic/ osteopathic manipulation was the most common (34%, 29/85) alternative therapy followed by massage, Reiki, acupuncture and Bowen therapy. Homeopathy, aromatherapy and magnetic therapy were also included but in less than five respondents per category.

9.3.6 Episode of lameness

The final section of the survey was comprised of five short questions to collect data regarding lameness in the same individual horse used throughout the rest of the survey. Of 438 respondents, 71% (309/438) of horses were reported to have experienced an episode of lameness within the last 12 months (figure 3). An examination was carried out by a veterinary surgeon in 79% (243/309) of lameness cases. A competition or event had been missed in relation to the episode of lameness in 61% (190/ 309) of responses.

9.3.7 Return to previous use

The horses were further categorised into those who were unable to return to previous level of work (25%, 78/309), those who did return after the lameness was resolved (55%, 170/ 309) and those who were currently undergoing treatment (15%, 47/309). The remainder of the population had failed to respond or responded with ‘unknown’ (14/309, 5%)(Figure 3).

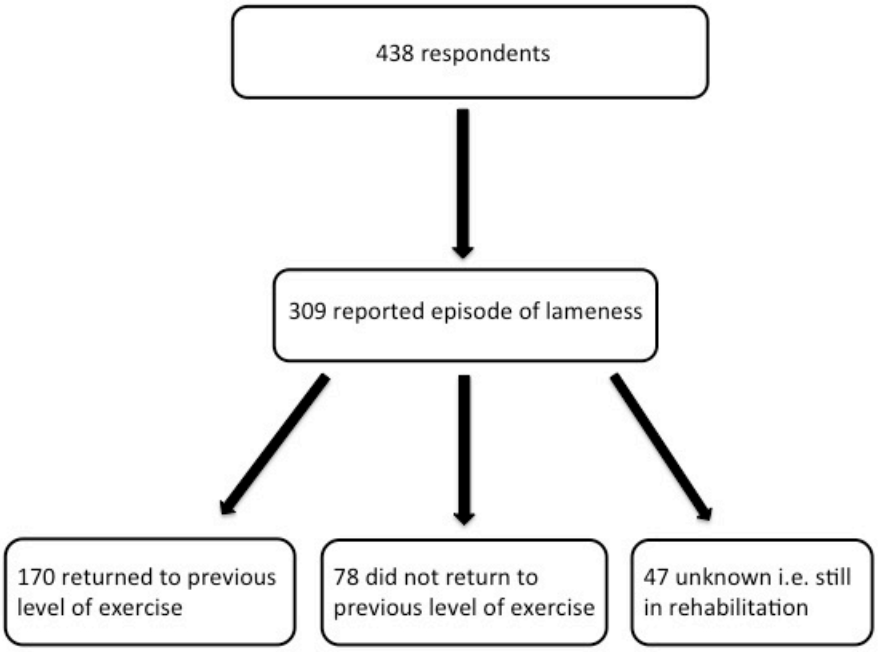


Figure 3: A flow chart to summarise the outcome of a single episode of lameness according to the respondents who completed the final section of the survey.

For those horses that returned to their previous level of work, the median period of time the horse was not in routine exercise was 44 days (IQR 17- 118 days). The group of horses who did not return to their previous level of work had a considerably longer period out of work with a median of 130 days (IQR 45- 228) before being either fully retired or performing at a lower level than before the episode of lameness (Figure 4). The term 'unknown' in Figure 3 relates to the number of horses who were neither confirmed to have returned to work, nor those who were fully retired. Therefore, this group of horses were considered to be either in rehabilitation of undergoing treatment for the episode of lameness. When the number of days out of full work was categorised, there was a significant increased risk that the horse would not return to full work after 90 and 180 days in comparison to the first category 0-14 days (OR 4.8, p- value 0.003; and OR 8, p- value <0.001 respectively) (Figure 5).

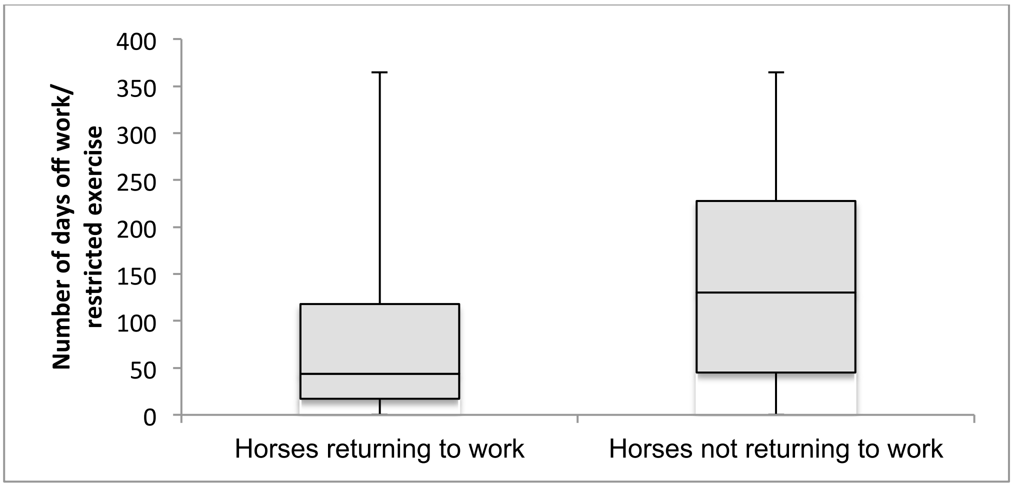
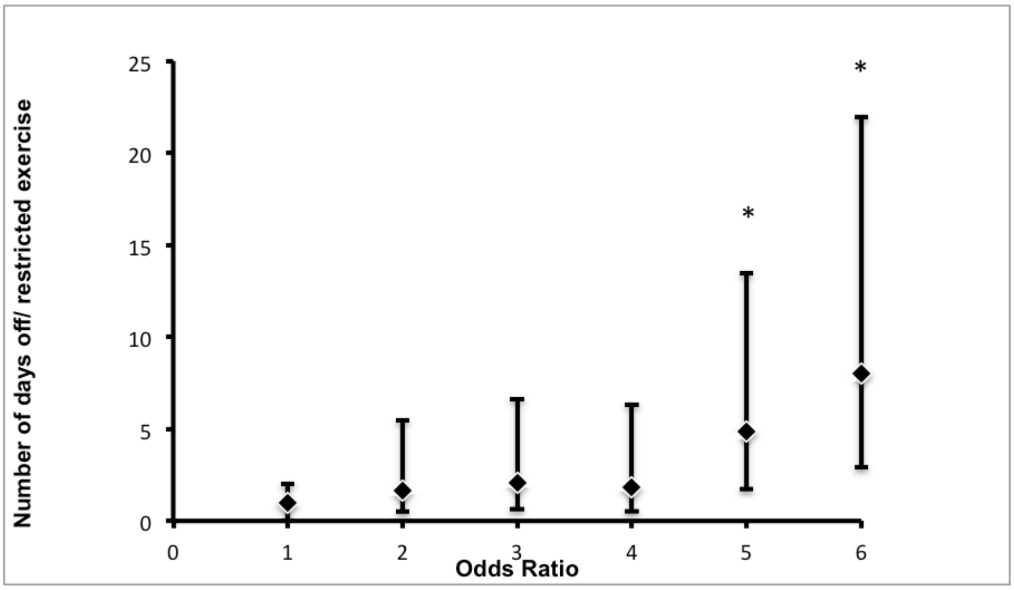


Figure 4: Comparison of number of days out of work between those horses that returned to previous use and those that did not.



Days off work	Odds Ratio	P- Value (*significance reached)	Lower 95%	Upper 95%
0-14	1	NA	1	1
15-30	1.67	0.4	1.16	3.82
31-60	2.05	0.23	1.41	4.55
61-90	1.81	0.34	1.29	4.51
91-180*	4.83	0.003*	3.1	8.63
181-365*	8	<0.001*	5.09	13.94

Figure 5: Graph and associated table of data to show the odds ratio of return to work compared to the first category (0-14 days) when the number of days off was categorised.

9.3.8 Response rates

In this study the total non- response rate was 58/ 609 (9.5%) which refers to those respondents who did not complete beyond the first section of the survey. The unit non- response rates were calculated following removal of the total non- responses, which identified less than 1% drop- out for each essential question (Figure 6, Table 6). The unit non- responses have been detailed in the graph below to demonstrate transparency of the dataset. There were 25 'essential' questions that required the respondent to enter a value before advancing to the next question. Where an 'essential' question had more than one sub- part, the respondent was not required to enter values for each part of the question to continue through the questionnaire. Due to this default mechanism that was undetected during the making of the survey, there are questions, which appear to have larger unit non- responses than expected for an essential question. The majority of the higher unit non- responses are linked to Section 3 where the respondents were required to enter detailed information regarding the cost of horse maintenance.

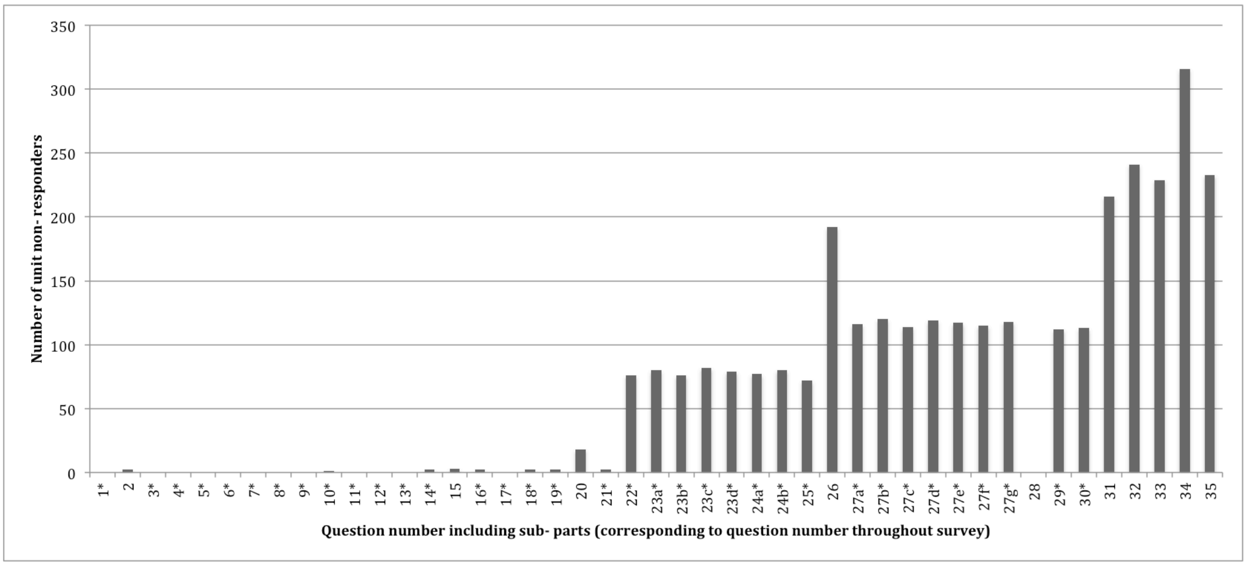


Figure 6: A graph to show the unit non- responses at each question (including sub- parts). Questions marked with an asterisk were 'essential' questions. Section 1: Q1-8; Section 2: Q9-17; Section 3: Q18-35.

Question	Question description	Number of unit non-responders
1*	County	0
2	Post code	2
3*	Owner sex	0
4*	Owner age	0
5*	Number horses	0
6*	Involvement	0
7*	Participation equestrianism	0
8*	Equestrian membership	0
9*	Horse name	0
10*	Horse age	1
11*	Breed	0
12*	Horse sex	0
13*	Duration ownership	0
14*	Owner- horse distance	2
15	Time spent	3
16*	Survey advertisement	2
17*	Purchase price	0
18*	PPE	2
19*	Insurance	2
20	Cost insurance	18
21*	Stabling facility	2
22*	Cost stabling	76
23a*	Vaccination	80
23b*	Worming	76
23c*	Dentistry	82
23d*	Farriery	79
24a*	Feed winter	77
24b*	Feed summer	80
25*	Feed supplement	72
26	Cost feed supplement	192
27a*	Cost competition entry	116
27b*	Cost transport competition	120
27c*	Cost lessons	114
27d*	Cost transport lessons	119
27e*	Cost swimming	117
27f*	Cost physiotherapy	115
27g*	Cost alternative therapy	118
28	Type alternative therapy	0
29*	Horse Age	112
30*	Episode of lameness	113
31	Vet exam	216
32	Number days rest	241
33	Number days restricted exercise	229
34	Return to previous work	316
35	Competition missed	233

Table 6: A table to show survey question and the number of unit non- responders. Each essential question is marked with an asterisks (*). The questions were divided into sections as follows- Section 1: Q1-8; Section 2: Q9-17; Section 3: Q18-35; Section 4: Q36-40.

The repeater question was completed by 438 respondents, from which an agreement of 98% was identified. Those respondents who did not fully complete Section 3, but had completed the first 2 sections were classified as 'late non- responders'. This population were compared with respondents who had completed Section 3 of the questionnaire as a test of reliability. The responders versus late non- responders were compared both geographically (Figure 7) and based on the descriptive variables within the first 2 sections of the questionnaire. Geographically there was no significance difference between drop- outs within the 12 regions of the UK. The South East of England had the greatest proportion of drop- outs (20%) but was also the region with the highest number of complete surveys. A greater proportion of individuals who had insurance dropped out of the survey at section 3 (p= 0.007), and those respondents that had a pre- purchase examination for their horse were more likely to complete the full survey (p= 0.006). There were a significantly lower proportion of drop- outs in the 25-34 year old age category in comparison with the other age categories (p= 0.03).

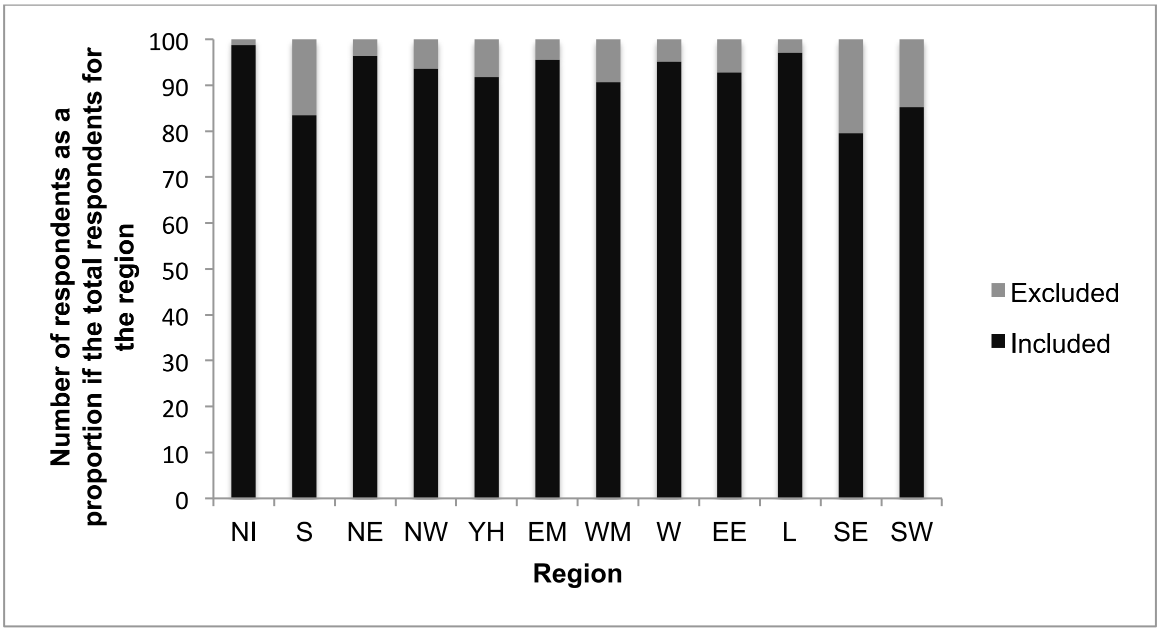


Figure 7: A graph to show the comparison of responders and late non- responders in association with each UK region.

9.4 Discussion

The results of this survey provide key information to allow the quantification of both the cost of equine ownership, and the financial impact of an episode of lameness associated with on- going basic maintenance costs when the horse is not in full use. The cost of inactivity has been clearly highlighted as an important value based on the daily basic maintenance cost of horse ownership, which prior to this study has been regarded as a 'hidden cost' of equine lameness. In this study, the cost of activity was viewed as the inability for the owner to use the horse for its designated purpose due to lameness. If the owner is unable to ride the horse, then the horse is not fulfilling its purpose in return for the cost of up- keep. This study presents similar findings on expenditure to those reported in large nationwide surveys conducted by the British Equine Trade Association (BETA 2015) and the National Equine Health Survey 2015 (Slater 2015). However in this case, the dataset provides additional information on both horse and owner, producing a more rounded description of the demographics of the respondent population.

The population in this survey were largely female; aged between 24 and 55; owned or cared for 2-4 horses and participated in horse riding for pleasure or low- level competition purposes. At first glance, this study population appears to be gender-biased compared to the reported population of UK riders (BETA 2015), however due to the online nature of the study we do not know if more men opted not to begin the survey after showing initial interest. The gender bias in this study means that respondent descriptive data and response rates cannot be compared between male and female respondents. Despite the increased number of respondents in Southern Scotland, the largest number of respondents by region was the South East of England. The Scottish population may be over- represented in comparison to other published data of UK horse location (Boden et al. 2013), however the survey was widely UK- distributed, predominantly through the medium of social media and a national equine publication, and there were no significant differences in response rates between these regions. This population may be comparatively over- represented because of advertising on local and regional Facebook and websites.

There is increasing popularity of online questionnaires for both survey provider and respondent (Boden et al. 2013), and this method of data collection is considered to be reliable (Ritter et al. 2004) and widely available. The use of an online survey inherently assumes that the respondent population have sufficient cognitive ability, access to the internet and are familiar with the use of a computer, therefore automatically excluding sub- populations of people who are more likely to submit an incorrect or incomplete survey (Bech & Kristensen 2009; Bälter et al. 2005). The reliability of this dataset was evaluated using the repeater question, response and non- response rates, and data consistency in comparison with other studies. The response rate exceeded the minimum number of respondents required to complete the entire survey, to complete at least two sections of the survey and also per question. Greater numbers of non- responses were seen in the non- essential questions, and generally those requiring data entry. The questions referring to specific costs in Section 3 were most affected (Figure 6). For this reason, we used those who did not complete Section 3 of the survey as 'late non- responses' and the information they provided was used only for descriptive analysis of the first 2 sections. Despite the significance of 3 influences related to the late non- response comparison, there is no clear association between the owners' age, whether a horse is insured, or has undergone a pre- purchase examination.

Web surveys which recruit respondents through web- based advertisement report average drop- out rates of 30-80% (Bosnjak & Tuten 2001; O'Neil et al. 2003), much higher than reported in the current study. In a review of survey drop- out rates, the balance between respondents' interest and their experienced burden is described. In all cases, a respondent will begin a survey with greater interest than experienced burden. The respondent drops out of the survey at the point where the burden of carrying on with the survey (boredom, technical difficulty) becomes greater than the level of interest (Galesic 2006). The most likely motivation for beginning the current survey was likely to have been interest in the subject as no financial or commercial rewards were offered for completion of this survey. Other incentives include the short duration of completion (less than 15 minutes) (Deutskens et al. 2004; Marcus et al. 2007) and the involvement of the owner from the beginning of the survey with an explanation of the study objectives in an introductory statement (Galesic & Bosnjak 2009).

The routine cost of horse ownership in this study was calculated using the basic expenditures incurred by all horse owners. Variable information exists regarding both overall population healthcare and specific financial outlay for basic routine maintenance, however studies focussed on the geriatric horse (Ireland et al. 2011), preventative healthcare measures (Ireland et al. 2013), gastrointestinal parasite control (Stratford et al. 2014), laminitis (Wylie et al. 2013a) and general management practices (Wylie et al. 2013b; Relf et al. 2012) in the UK detail various aspects of financial commitment associated with routine practices and costs.

The current study has identified factors that affect the cost of daily ownership. Keeping a horse in full livery compared to keeping a horse on one's own premises was the most marked difference at four times the daily cost (£16.50 versus £4.10 respectively). Other variables included equine insurance; use of the horse for competition purposes, a higher level of competition; and the region of the UK where the horse was stabled. Although these factors are logical cost increases, there has been no previously published data, nor approximate values of financial outlay. The additional costs included the use of feed supplements and alternative therapies. The use of feed supplements in this study was reported at a lower frequency than in other studies (Hoffman et al. 2009; Murray et al. 2015), however it must be noted that these surveys were nutrition- based and therefore we could assume an increased bias towards respondents with an interest in feeding practices. Alternative therapies were comparable with other reports with regards to variation in choice of therapy. We initially chose to include physiotherapy within this group for the purpose of data collection. The frequency of use and cost of physiotherapy was analysed separately due to the substantial number of respondents in comparison to the remaining alternative therapies.

The impact of equine lameness upon an owner was divided into two major considerations; the time allocation and financial outlay of a single episode of lameness through temporary loss of use. Over two thirds (65.7%) of this population spend more than 10 hours per week caring for the basic needs of their horse. The difference in time spent on basic horse maintenance following a period of lameness is highly variable and outwith the aims of this study. The intention of this study was not to provide a robust, representative estimate of prevalence of lameness, however the findings are comparable to that available in literature for non- race horses spanning the last 20 years (Slater 2015; Kaneene et al. 1997; Cole et al. 2005; Murray et al. 2010). A recent US-study identified that 52.8% of horses were lame during pre- purchase examination (Van Hoogmoed et al. 2003), higher than any other reported prevalence. In the current study, it should be noted that the prevalence of lameness and the number of days of reduced use are owner reported and therefore less reliable data. The majority of horse owners sought veterinary attention for the episode of lameness however further clinical information describing the nature of the lameness was out-with the scope of this survey. The reported returns to exercise following an episode of lameness in this study are not available within current literature, other than in retrospective studies specifically describing a clinical condition. In some cases, owners offered information such as retirement of horse or change of use to brood mare therefore, the duration of restricted exercise in those horses that did not return to previous use must be interpreted with a degree of caution.

9.5 Conclusion

This study has allowed us to characterise the cost of horse ownership in the UK amongst a population of horse owners who broadly fit under the 'pleasure horse' owning category with the aim of determining the financial impact of lameness. It has provided valuable information about a subset of equine owners who are frequently clients of UK equine practices i.e. insured, general purpose, and low to medium- level competition horses. Our study used a diverse sample of owners with respect to age, use of horse and geographic location, increasing the depth of the information attained within a specific population. The results of this questionnaire provide a unique dataset that considers the financial outlay and time allocation required with horse ownership, and the impact of a single episode of lameness in relation to these baseline costs. The financial impact of restricted exercise should be considered when making further investigation and treatment decisions.

10 Chapter three: A review of current methods of equine lameness evaluation

10.1 Subjective lameness assessment

Lameness is a behavioural adaptation to the noxious stimuli caused by the presence of pathology (Ashley & Whay 2005). Subjective assessment of equine lameness is most commonly described using numeric or verbal rating scales, usually ranging from 0-5 or 0-10 (Peham et al. 2001). Subjective assessment has been proven to have high inter-assessor variability of lameness grading and selection of lame limb (Keegan et al. 2004). In a study investigating the repeatability of subjective lameness examination carried out by experienced clinicians, the overall between-evaluator agreement was only considered to be "marginally acceptable" with agreement for forelimb lameness of 22- 36% above chance and agreement for hind limb lameness of 14-19% above chance. Overall this study showed that the subjective evaluation of equine lameness, especially when it is of mild severity, is not reliable (Keegan et al. 2010). These results have been reproduced in several studies and it is widely appreciated that subtle lameness is inherently difficult to quantify and agreement declines after multiple examinations (Keegan et al. 2004; Keegan 2007; McCracken et al. 2012). The intra-assessor variability is reduced with level of expertise demonstrated in studies comparing clinicians with residents and interns (Keegan et al. 1998). In cases where a horse presents with very mild lameness, exacerbation of lameness (change of surface) or provocation of the lameness (flexion tests) is required (Ross & Dyson 2011). Video recordings of horses have been used to report the accuracy and sensitivity of subjective evaluation of mild lameness in horses. The use of video recordings of horses at walk and trot to assess gait has been criticised for the inaccuracies associated with observer error in viewing a horse on a screen and not first hand (Fuller et al. 2006). In a study investigating bias with the use of local anaesthetic nerve blocks, observers only had to agree that the horse got worse, stayed the same, or got better to reach agreement. No quantitative assessment of the change in lameness was required. Despite the ease expected to reach agreement, the agreement between observers was low. The paper concluded that when horses demonstrate a mild degree of lameness, agreement among veterinary surgeons performing subjective lameness evaluations with diagnostic anaesthesia is poor and subject to bias (Arkell et al. 2006). The poorest correlation of inter and intra-assessor repeatability scores are seen in mild hindlimb lameness (Keegan et al. 2001).

10.2 Objective lameness assessment

Objective lameness assessment is a constantly developing area of research. Kinetic and kinematic gait analysis systems have been developed in an effort to detect and quantify gait abnormalities in the horse. Kinematic analysis measures the geometry of movement without considering the forces that cause the movement. At the present time, the majority of kinematic evaluations are performed using videographic or optoelectronic systems. Kinetics is the study of the forces that are responsible for the movements. A variety of transducers, including strain gauges, piezoelectric and piezoresistive transducers and accelerometers, are used in kinetic studies to determine the differing forces exerted between lame and non- lame limbs. Several transducers have been combined to develop force plates and force shoes for measuring ground reaction forces (Keegan 2007).

Force plates were previously considered to be the gold standard objective technique, however with the development of economically viable, more user- friendly equipment, their use has decreased. Quantitative methods that have been used to analyse head movement in forelimb lameness include measurement of vertical displacement and acceleration of the head (Buchner et al. 1996) , comparison of the minimum head height during each stance phase of the stride (Keegan et al. 1997), stride length (Wright 1993), frequency spectral analysis of vertical head motion (Audigié et al. 2002; Peham et al. 1996) and use of a time domain signal decomposition that assumes vertical head movement to be a combination of regular periodic and irregular random motion (Keegan et al. 2001). By removing the irregular random motion from the acquired data, the vertical displacement of the head and pelvis can be measured and compared between right and left sides. The study of this asymmetrical movement in lame horses has become the latest development in kinematic gait assessment.

Similar methods that have been used to evaluate hindlimb lameness include measurement of vertical displacement and acceleration of the sacrum (Buchner et al. 1996) , comparison of the minimum head height during each stance phase of the stride (Kramer et al. 2000), frequency spectral analysis of vertical sacral motion (Peham et al. 2001; Peham et al. 1996), comparison of the ratio of left to right tuber coxae vertical excursion (Kramer et al. 2000) and signal decomposition of evaluating pelvic movement (Keegan et al. 2004).

The most widely used kinematic system is called the Lameness Locator®[3]. It is a wireless, inertial sensor device which uses a single gyrometer and two accelerometers to detect and measure lameness based on amplitude of displacement of the head and pelvis greater than a threshold below which is considered to be normal. Data collection is live and data analysis can be achieved within a few seconds. The system is easy to use and has proven useful in the evaluation of equine lameness in clinical practice (McCracken et al. 2012). Studies carried out testing the reliability of this technique have been validated objectively with the use of a stationary force plate (Keegan et al. 2010) and subjectively with the use of trained subjective assessors (McCracken et al. 2012; Ishihara et al. 2005). Inertial sensor-based systems have been shown to correctly select the lame limb at a lower degree of lameness than trained assessors (McCracken et al. 2012). One constraint of quantitative measurement is that variability between individual horses will affect the response to certain interferences (Clayton & Schamhardt 2001) such as repeated trotting, flexion tests and diagnostic anaesthesia. Despite this variability, the Lameness Locator® has been validated for repeatability of measures in both hindlimbs and forelimbs (Keegan et al. 2011); ability to detect mild lameness (Keegan et al. 2011; McCracken et al. 2012); ability to detect increase in lameness severity (Marshall et al. 2012); ability to detect decrease in severity (Maliye et al. 2013); and ability to detect compensatory lameness in other limbs (Maliye et al. 2015). Body- mounted sensor devices have been developed for lameness detection in horses and are currently used worldwide by general practitioners in the field. The commercial use of objective lameness assessment has been developed due to the ease of use of the system, the small size of sensors and the wireless transmission of data (Keegan et al. 2013).

10.3 Lameness grading

A scale of measurement is valid when it can be shown to measure the property for which it was developed consistently and accurately in comparison with a gold standard. However, there is no gold standard to assess locomotion in any species (Keegan et al. 1998; Whay 2002; Hudson et al. 2004; Quinn et al. 2007) due to the subjectivity of assessment and differences in the way that individual observers define objective rating categories. The term 'validity' also relates to the absence of bias in results where the study population will have the same value as the true measure in the target population. Knowing the reliability of a particular scale, a clinician can judge whether the observed differences are real or merely the result of errors of measurement.

[3] www.equinosis.com

There are three commonly used rating scales which have been extrapolated from human medical research and are used to assess lameness in animals. A numeric rating scale (NRS) is a subjective measurement scale of a clinical sign/ syndrome in which numerical scores are given. A description may be given for each score. The observer chooses, for each individual observed, the number on the scale which they consider most closely matches that individual. An NRS can be used without descriptors but is improved by their addition. In short, these are discontinuous, ordinal scales, with good repeatability between similarly experienced clinicians (Keegan et al. 1998). Verbal rating scales (VRS) are simple descriptive scales, which consist of a list of adjectives that describe different levels of pain. The least intense descriptor is usually given a score of 0, the next a score of 1, and so on until each adjective has a number score associated with it. These can be used in composite pain scales to produce an overall pain score but alone are prone to criticism due to their subjectivity and lack of quantitative information for statistical analysis. These are useful for rank- ordering of pain states which can be helpful in humans to ensure that treatments being provided are having a meaningful effect on the patient (Hartrick et al. 2003). A visual analogue scale (VAS) consists of a horizontal line (100mm in length) reflecting degrees of pain severity, anchored by various descriptors from ‘no pain’ to ‘worst pain imaginable’. A pain severity VAS may have multiple gradations using specific adjectives to mark a certain point along the line. The specific adjectives used vary from version to version. Patients put a mark along the line to describe how severe their pain is. The score is measured from the zero anchor to the patient’s mark. In total there are 101 measures of pain along the line (Williamson & Hoggart 2005). Visual analogue scales are continuous and sensitive but can be poorly repeatable in behavioural assessment of pain in animals such as horses and donkeys (Ashley & Whay 2005). However, this method of recording has been shown to be valid and repeatable for assessment of mild- moderate, naturally- occurring lameness in dogs in comparison with objective gait analysis using force plate analysis (Hudson et al. 2004).

Composite pain scales are briefly mentioned here because of the emotional component of pain which is not accounted for in numeric scales, for example change of behaviour or demeanour (aggressive tendencies in chronic or severe pain) (Ashley & Whay 2005). These are complex and multidimensional scales, which are used in pain assessment. These are typically used in a hospital setting to assess behavioural indicators of pain in acute trauma or post-operative patients (Bussières et al. 2008; Ashley & Whay 2005). An ideal pain scoring system should be linear, weighted, sensitive to pain type, breed- and species-specific, less dependent on observer and closed to misinterpretation. These have been developed in veterinary medicine for use in cats (Holden et al. 2014; Calvo et al. 2014) and horses (Gleerup et al. 2015; Gleerup & Lindegaard 2015). The use of a composite pain scale such as this is out of the scope of this research, however, the general demeanour and gait of the animal may be important for owners' assessment of the severity of their horse's lameness. Therefore, the use of behavioural changes alongside gait changes should be taken in to account when asking owners to interpret the severity of their horse's lameness.

10.4 Comparison of scales

Pain scales with more response levels e.g., the VAS or 0–10 NRS and VRS have the potential to be more sensitive (Williamson & Hoggart 2005), although more response categories do not necessarily translate to more reliable responses. NRS and VAS might be considered first when particularly sensitive measures of pain intensity are needed (Ferreira-Valente et al. 2011). Visual analogue scales have numerous qualities which can lead to responder error, varying depending on the type of study being carried out, for example bipolar disorder severity of depression versus chronic pain scoring (Ferreira-Valente et al. 2011). Old age and cognitive dysfunction are consistent risk factors for responder error in studies which use visual analogue scoring methods (Jensen et al. 1986; Wewers & Lowe 1990). Visual analogue scales are typically measured in millimetres and can be used as a percentage. NRS are given an overall score, which can be converted into a ratio. Ratio scales permit the user to perform calculations such as percentage improvement in pain scores. This ability is clinically desirable for measuring response to treatment.

For the veterinary surgeon assessing equine lameness, a numeric grading scale is the most commonly used method of reporting and allows better understanding of case-based discussion amongst clinicians. In general, those with similar levels of experience have good inter-observer reliability (Keegan et al. 2004; Keegan et al. 2013) and agreement of lameness assessment. The untrained observer or those with little experience have very little inter-observer agreement, indicating that in this case a numeric rating scale is not a reliable means of data collection for lameness assessment. Subjective evaluation varies between observers based on the assessed criteria, the clinical presentation of the gait abnormality (Dyson 2011) and the owner's primary complaint with respect to the horse's performance.

10.5 Effect of lameness on the horse owner

Despite the fact that equine lameness prevalence studies, and indeed any veterinary orthopaedic examination of a horse relies upon the owner recognising and reporting the animal as being lame, we know very little about how horse owners assesses equine lameness. Earlier discussion in this review chapter compared the reliability of lameness assessment between trained professionals and veterinary students (Fuller et al. 2006; Keegan et al. 2010) which demonstrates the discrepancy in experience and training in such a field between the trained and untrained observer. To the author's knowledge, no studies exist which compare the trained professional with minimal prior experience of the animal in question with an untrained assessor who has only prior knowledge of the animal and limited experience in lameness assessment. Assuming the trained professional assesses the horse using a standard orthopaedic examination technique, the difference of opinion between owner/ carer and veterinary surgeon may be of interest to allow better understanding between the two parties.

11 Chapter four: Comparison of lameness assessment according to a horse owner, a veterinary surgeon and a validated inertial sensor device in a referral hospital setting.

11.1 Introduction

Reliable assessment of equine lameness is a clinical challenge due to the variability between observers and the variability and bias of a single observer within the same examination following limb manipulations and diagnostic anaesthesia. The currently accepted standard of practice is the subjective lameness examination. Experience and training in orthopaedic assessment of lame horses, ranging in severity, has been shown to improve the consistency of subjective lameness examination (Arkell et al. 2006). Despite the appreciation that training improves the quality of the lameness examination, inter- observer agreements between orthopaedic specialists remain poor regarding severity of lameness and effect of diagnostic anaesthesia, particularly in cases of mild lameness (Keegan et al. 1998). This finding has been attributed to the use of multiple lameness scales of varying complexity, each of which may be interpreted and utilised in an individual manner (Dyson 2009). Multiple studies of inter- and intra- observer agreement exist, however previous comparisons of subjective evaluation have been carried out using videography without audio (Hewetson et al. 2006; Fuller et al. 2006), using horses on a treadmill (Keegan et al. 1998), and generally on smaller numbers of horses (Arkell et al. 2006). A more recent study of 131 horses has shown comparatively higher agreement scores when the assessors observed the horse in a live environment with horses moving over ground, during lunging as well as in a straight line and following flexion tests (Keegan et al. 2010).

Studies carried out using the Lameness Locator® in a clinical setting using horses with naturally occurring lameness have validated its use in detecting improvements in a lame limb following diagnostic anaesthesia and changing patterns of compensatory lameness attributed to the change in severity of primary lameness. The increasing use of objective lameness evaluation devices, highlights a marked discrepancy between the experienced subjective observer and the objective data. As the Lameness Locator measures only the vertical displacement of the head and pelvis, we must consider other ways in which horses demonstrate lameness, for example reduced stride length, propulsion or postural abnormalities such as stiffness. Further work to determine the change in gait that is most appreciated by the observer is warranted (Maliye 2015).

Agreement studies typically assess experienced and inexperienced observers, all of whom have a basic knowledge of the orthopaedic examination of the horse. During a standard lameness assessment, the veterinary surgeon applies their own method of examination and uses some form of numeric and/ or qualitative rating scale to record the severity of the lameness and the limbs affected. Despite the natural variation of interpretation of lameness scales, the individual way of carrying out an orthopaedic examination and assumed human error, most examinations are carried out in a similar form according to standardised teachings and available texts. As professionals, we consider the general public as 'untrained' individuals with regards to the equine orthopaedic examination. Equine owners have a broad range of knowledge and experience of normal gait for individual horses under their care. For the purposes of this study we will refer to them as 'experienced' in comparison to the non- horse owning population.

There is relatively scant evidence in the current literature describing how experienced but untrained persons assess equine lameness. Perceptions of lameness may include changes in normal behaviour; development of abnormal behaviour; change in reaction to handling; changes in demeanour, posture, activity or performance; and change in gait (Sneddon et al. 2014) . In a comparison of owner- reported health problems with veterinary assessment of geriatric horses in the UK, lameness was present in 50% of horses but reported by only 23% of owners (Ireland et al. 2012). A study of owner reporting of equine lameness in pony club horses in Australia identified that owners were most likely to contact their veterinary surgeon when either behaviour changes have a negative impact on the horse and rider or when optimal performance is not reached (Buckley et al. 2004). Owner interpretation of lameness is important for detection and monitoring purposes. Comparison of owners' evaluation of lameness with a veterinary surgeon and a kinematic device has not previously been examined.

The aims of the following study were to investigate reasons for referral and owners' general assessment of lameness prior to veterinary examination; to quantify and compare lameness severity using subjective and objective methods of assessment; and to determine the areas of best agreement between subjective evaluation (owner; veterinary surgeon) and objective evaluation (Lameness Locator®).

11.2 Materials and Methods

11.2.1 Horses

Horses presenting to the Weipers Centre Equine Hospital for investigation of lameness or poor performance were recruited. All horses in this study had been referred by a first opinion veterinary surgeon. Horses were included in the study if they were mature (>2yo) and broken-in for riding purposes. All horses were able to trot in- hand with a loosely held lead rein attached to the head collar or bridle. Horses excluded from the study were those which presented with severe, acute onset lameness, developmental disease (OCD, FLD, ALD) and animals that were previously treated for the same cause of lameness i.e re- check examination. All horses were considered to have a mild- moderate lameness of either forelimb or hindlimb in origin. Horses determined to have an AAEP lameness grade of 4 or 5 were not included in this study. Permission for use of the Lameness Locator®, and the data subsequently collected, was obtained by the owner prior to the beginning of the lameness examination.

11.2.2 Instrumentation

All instrumentation, data acquisition and analysis were performed as previously described (Keegan et al. 2011). Each horse was fitted with a single-axis accelerometer on the dorsal aspect of the head and pelvic tuber sacrale, and a single-axis gyroscope was fitted to the dorsal aspect of the right forelimb pastern. The head and pastern sensors were fitted into a specifically designed neoprene cap and pastern wrap, held in place by the poll piece of the head collar, and a Velcro patch on the wrap respectively. The pelvic sensor was secured by placing a section of adhesive velcro tape on the midline over the tuber sacrale and securing it with adhesive tape (Duct tape). The head and pelvic sensors were secured using strips of adhesive tape (Duct tape) as required. The pastern wrap was further secured with cohesive bandaging material (Vet Wrap). (Photograph 1).

Figure 8: A horse instrumented with inertial sensors on the head, right forelimb pastern and tuber sacrale. Photograph taken by Kathy Uprichard

11.2.3 Sensors

The commercially available sensors are comprised of either a single-axis accelerometer or gyroscope, a radio transceiver (Bluetooth Class 1) and antenna, 4.2 V lithium-polymer battery, microcontroller and circuitry, all contained within an epoxy case. Each sensor measured 3.7 x 2.5 x 1.3cm and weighed approximately 30g. Sensors make up a local area network of a master node located on the tablet computer (Lameness Locator tablet) and 3 slave nodes to which it is connected wirelessly. Data is digitally recorded (8 bits) in real time at 200 Hz. A 5ns per sample timing accuracy is achieved by synchronising the 3 channels using an onboard 40 MHz crystal with an accuracy of 10 ppm.

11.2.4 Accelerometry data

Data was analysed using commercially available software as previously described (Keegan et al. 2004). Briefly, vertical head and pelvic movement were analysed by measuring patterns obtained from the head and pelvic acceleration and right forelimb pastern angular velocity data recorded by the sensors. Collected data is then double-integrated and processed with a moving window, integration error correction algorithm. The signals produced are separated into 2 harmonic components and a random component, the latter component removed. The 2 harmonic components are summed in order to establish the gross vertical head and pelvic movement. Stride rate and stance data are recorded by the right pastern gyroscopic sensor and used to determine the temporal relationships of the gross vertical movement of the head and pelvis to the stride sequence. Please see abbreviations for definitions of Lameness Locator output data (HDMax, HDMin, PDMax, PDMin)

11.2.5 Owner Questionnaire

A clinical history was obtained from the horse owner by final year undergraduate veterinary students on clinical rotation at The Weipers Centre, and the owner was also asked to complete a short questionnaire (Appendix13.2.2). The questionnaire involved some repetition of the history obtained by the students; completion of a descriptive rating scale of the severity of the horse's lameness (mild, moderate or severe) and a visual analogue scale (VAS) scoring system used to assess the owner's perception of the severity of their horse's lameness. The descriptive section of the questionnaire was completed by the horse owner at the beginning of the consultation, and any concerns which arose regarding its completion were discussed verbally with the veterinary surgeon. The VAS scores were completed during the consultation where the horse was walked and trotted in a straight line and if deemed necessary by the clinician, in a circle. The owner and veterinary surgeon did not discuss the severity of the horse's lameness during the examination until after the VAS scores had been completed. For the owner population of assessors, the VAS scores did not require the owner to isolate the lame limb. There were VAS scoring lines for lameness evaluation at walk and trot, and also for more subjective questions such as the horse's demeanour and the owners' interpretation of the level of discomfort the horse was in at the time of the lameness examination. The questionnaire was designed to allow all of the necessary orthopaedic data (history of ownership, shoeing, lameness and owners perception of the horses lameness and VAS of the current lameness) to be included in a single form. Incomplete questionnaires were excluded from the study.

11.2.6 Pilot study

The questionnaire was piloted amongst a population of 5 experienced horse owners within the University of Glasgow (Appendix 13.2.1). Pilot respondents were asked to critique the wording, the layout of the questionnaire, the number of questions, the style and level of difficulty of the questions and the overall length of the questionnaire. The questionnaire was refined in response to this exercise and the results from this pilot study were not included in the analysis.

11.2.7 Lameness Examination

A full clinical examination was carried out on each horse that presented for lameness examination including a general physical examination and a more specific musculoskeletal examination. The musculoskeletal examination included static manipulation of the soft tissue and bony structures of the limbs and hoof testers applied to the feet if warranted. This was followed by a dynamic lameness examination. A minimum of 25 strides at trot in a straight line was required for the acquisition of data from the Lameness Locator®. Horses were walked and trotted in hand in a straight line on a concrete surface. Flexion tests (limb held in flexion for >30 seconds) and trotting on the right and left reins of the lunge on a soft surface were carried out at the clinicians' request. The base straight- line examination at trot, and lunging on both reins was recorded using the Lameness Locator. Flexion tests and gaits other than trot were not included in the Lameness Locator data collection. Clinicians were required only to select the most lame limb in cases of multi- limb lameness. The AAEP lameness scale was used to numerically record the severity of lameness.[4]

11.2.8 Visual Analogue Scale (VAS) Scoring

A visual analogue scale (VAS) for severity scoring each limb was completed by the clinician after assessing the horse at trot (Appendix 13.2.3). An 'X' was placed on each line between 0 and 100mm with markers of 100% sound and non weight- bearing lame on the left and right ends of the line respectively. A VAS score was assigned to each limb totalling four VAS scores for each horse. Only the most lame limb VAS score was utilised in cases of multi- limb lameness. The clinician also evaluated the horse's overall level of comfort based on general gait and willingness to move. The VAS score was an assessment of the baseline lameness, recorded before the lameness examination progressed to further diagnostic tests for example diagnostic anaesthesia and diagnostic imaging. Simultaneously, the Lameness Locator® provided data on each individual limb at trot in a straight line. The horse was also given a lameness score based on the AAEP lameness scale. Any other comments such as gait abnormalities, foot/ limb

[4] http://www.aaep.org/info/horse-health?publication=836

conformation abnormalities were also recorded. In total there were three assessors, all of which were boarded specialist surgeons (European and/ or American college of Veterinary Surgeons) and experienced orthopaedic clinicians.

11.2.9 Pilot Study

Amendments to the pilot version of the paper survey included the addition of specific questions to the section regarding the owners' appreciation of their horse's lameness so that the severity of lameness could be categorically recorded (mild/ moderate/ severe) as well as in both free text format and continuous numerical form (VAS score). Based on the pilot study, respondents were informed that the survey would take approximately 15 minutes to complete, and were informed of the study objectives in the format of a simple introductory paragraph. It was decided that the questionnaire should also be explained verbally so that that the VAS scoring system was clearly described. Overall the question wording, and the layout and style of questionnaire were deemed appropriate for horse owners.

11.2.10 Information obtained

Horse owner

1. Qualitative information regarding horse's general management and reason for veterinary intervention and referral
2. VAS score of the horse at trot during the lameness examination
3. VAS score of the horse's overall level of discomfort during the lameness examination

Veterinary surgeon

1. VAS score of the lameness severity based on the overall lameness examination
2. VAS score of the horse's overall level of discomfort during the lameness examination
3. AAEP lameness grade for the predominantly lame limb

Lameness Locator

1. Head Diff (Mean/ Standard deviation) min and max
2. Pelvis Diff (Mean / Standard deviation) min and max

11.2.11 Data Analysis

Qualitative population statistics were used to describe the horse and owner population. The lameness grade for the most lame limb was recorded numerically using the AAEP lameness scale as per hospital protocol for standard lameness examination. The lameness grade for the predominantly lame limb was used to describe the median severity of lameness however further analysis of this was outwith the aims of this study. The severity scores for the predominantly lame limb were used for correlation analysis when comparing the veterinary surgeon and the Lameness Locator. Correlation between subjective and objective parameters was determined using Spearman's rank correlation coefficient. The correlations were carried out between each of the three assessors using the visual analogue scales as continuous data for both subjective assessor groups. Agreement analyses were carried out only between owner and veterinary surgeons visual analogue scale scores using Bland Altman analysis. Horses were excluded from the correlation analysis where the trained subjective assessor and the objective assessor did not agree on the predominantly lame limb. The data for this section was carried out using R Project (R Team 2013) for statistical computing.

Spearman's rank correlation coefficients were described as follows:

Spearman's rank correlation coefficient	Descriptive correlation
0- 0.19	very weak
0.2- 0.39	weak
0.4- 0.59	moderate
0.6- 0.79	strong
0.8- 1.0	very strong

11.2.12 Vector Sum (VS), PDMax and PDMin

The quantitative data provided by The Lameness Locator included the HDMax, HDMin, PDMax and PDMin. Forelimb lameness was determined using the Vector Sum (VS) (Keegan et al. 2001; Keegan et al. 2004), which served as a vector- like measurement of head movement asymmetry between the right and left forelimbs. The vector sum (VS) was calculated as:

$$\sqrt{((HDMax)^2 + (HDMin)^2)}$$

The VS was calculated for each horse and was sign corrected according to predominant left or right forelimb lameness. In conjunction with the negative sign (-ve) of the HDMin attributed by the Lameness Locator to signify a left- sided lameness, a negative sign was therefore assigned to all forelimb lameness classified as left in origin. Hindlimb lameness was determined using the maximum and minimum pelvic difference (PDMax and PDMin respectively) from the Lameness Locator output. Again, negative values were considered to originate from the left hindlimb. For the purposes of further correlation and agreement analyses of lameness severity, all values classified as left- limb lameness in origin were multiplied by -1.

The overall predominant lame limb was determined by comparing the magnitude of the VS with the PDMax and PDMin to determine whether the Lameness Locator identified a forelimb vs hindlimb lameness, and also comparison of left and right sides according to the asymmetry of head (forelimb lameness) or pelvic (hindlimb lameness) measures of vertical displacement.

11.3 Results

11.3.1 Horses

Forty- five horses (20 mares, 25 geldings), mean age 10 years (range 4- 22), and body weight 570kg (range 425- 700kg) were recruited. There was a range of 14 breeds and all horses were used for general purpose riding and/ or low- level competition. Ninety- one per cent of the population were shod on all four feet (41/45), 7% (3/45) were barefoot trimmed and one respondent did not complete the question. Prior to the on- going episode of lameness, the horses were exercised at a median frequency of 5 times per week (range 3-6). Forty four per cent of the horses (20/45 horses) had previously been affected by an episode of lameness.

11.3.2 Owner questionnaire

Owners were asked to report on the reason the horse was initially examined by a veterinary surgeon. The response was in free text format and resulted in a total of 60 descriptions recorded for 45 horses. Lameness was the most frequently reported clinical sign prior to veterinary examination (28/60, 47%), alongside altered movement, evidence of a pain focus and behavioural changes noted by the owner (Figure 9). Sixty- eight per cent of owners reported that the episode of lameness had been less than 3 months duration before the horse was referred for specialist orthopaedic evaluation (Figure 10). The most commonly owner reported reason for specialist referral was that their first opinion veterinary surgeon had advised to do so (15/45, 33%). Other reasons included lack of current diagnosis, lack of improvement and the need for further diagnostic tests (Figure 11).

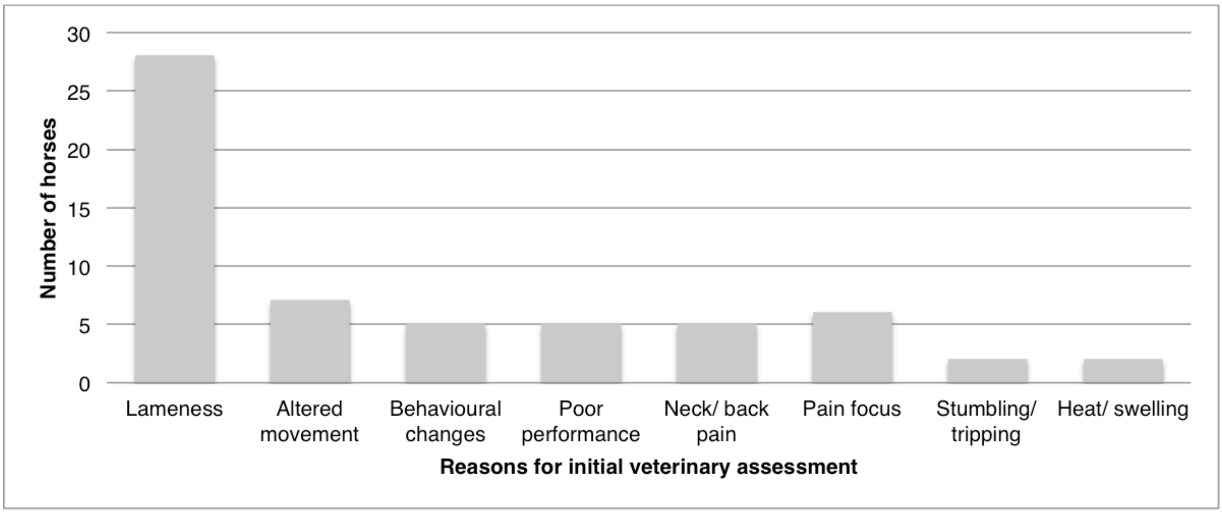


Figure 9: A graph to show the owner- reported reasons for initial veterinary assessment within the population of study horses

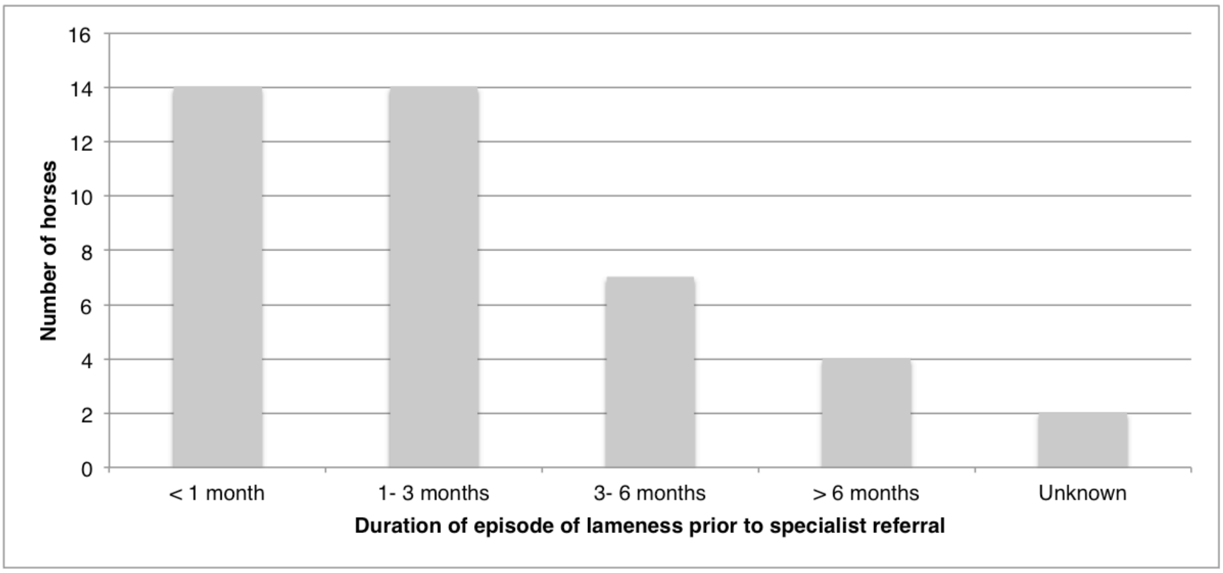


Figure 10: A graph to demonstrate the duration of the episode of lameness prior to specialist referral within the population of study horses

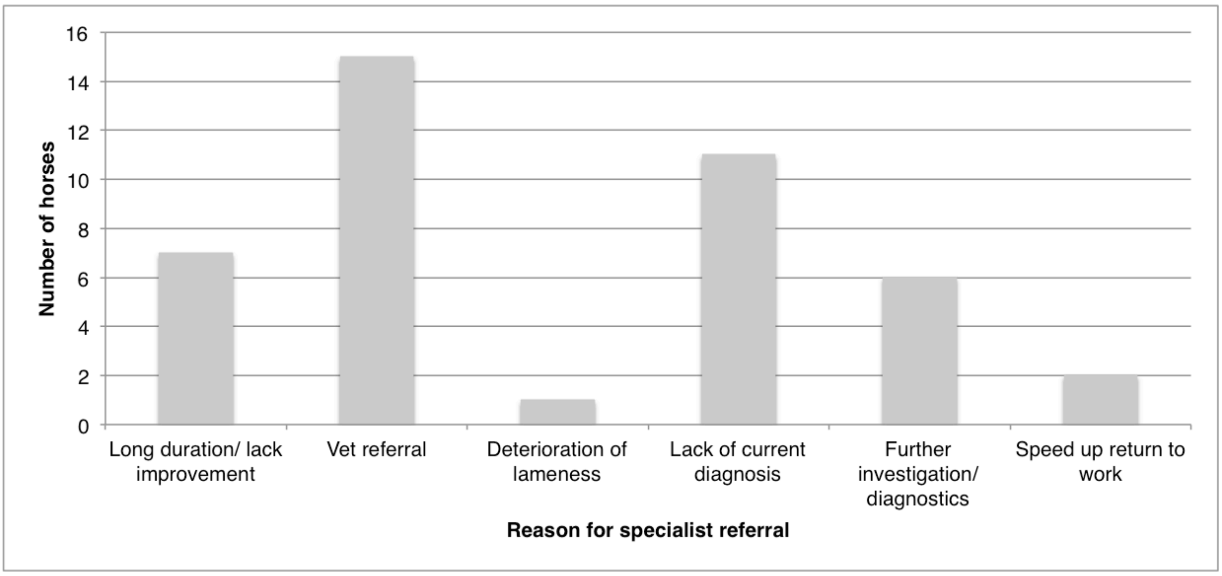


Figure 11: A graph to show the owner reported reasons for specialist referral within the population of study horses

11.3.3 Lameness evaluation

11.3.3.1 Lame limb selection

The median AAEP lameness grade recorded for the population of horses was Grade 3/5. Trained subjective (veterinary surgeon) and objective (Lameness Locator ®) methods of lameness assessment agreed on whether the predominant lame limb was a fore or hindlimb in 100% (45/45) of cases. In 88% (14/16 horses) there was agreement between the right and left sides in forelimb lameness and 93% (26/28) in cases with predominant hindlimb lameness. One horse was excluded due to lack of lameness, for which there was agreement from both subjective veterinary assessment and objective analysis. This particular horse was later diagnosed with, and treated for, impingement of the dorsal spinous processes. In cases where the subjective and objective assessors did not agree on the predominantly lame limb, the subjects were removed from the analysis of the severity of the lameness. The raw data is presented below as severity of lameness at trot for each of the 3 assessors for forelimb and hindlimb lameness respectively (Tables 7 and 8).

	Lameness Locator Severity		Clinician Severity			Owner Severity	
Horse Number	LL lame limb	Vector sum	Clinician lame limb	Trot VAS	Discomfort VAS	Trot VAS	Discomfort VAS
1	LEFT	19.8	LEFT	56.8	34.7	86.3	54.7
2	LEFT	17.1	LEFT	27.4	0.0	3.2	12.6
3	RIGHT	26.2	RIGHT	53.7	0.0	46.3	51.6
4	LEFT	34.0	LEFT	71.6	42.1	67.4	18.9
5	RIGHT	6.6	RIGHT	12.6	0.0	46.3	5.3
6	RIGHT	17.4	RIGHT	20	40.0	31.6	50.5
7	LEFT	6.9	LEFT	30.5	8.4	17.9	0.0
8	RIGHT	28.4	RIGHT	30.5	0.0	23.2	28.4
9	RIGHT	9.9	RIGHT	58.9	12.6	30.5	33.7
10	RIGHT	17.5	RIGHT	54.7	18.9	68.4	58.9
11	RIGHT	11.7	RIGHT	18.9	0.0	54.7	13.7
12	RIGHT	21.5	RIGHT	50.5	21.1	51.6	49.5
13	LEFT	25.8	LEFT	61.1	31.6	48.4	45.3
14	RIGHT	7.6	RIGHT	14.7	0.0	32.6	6.3

Table 7: A table to show data produced by all three assessors for predominant lame limb; lameness severity scores and discomfort severity scores for forelimb lameness.

	Lameness Locator Severity			Clinician Severity			Owner Severity	
Horse Number	**LL lame limb**	**PDMax**	**PDMin**	**Clinician lame limb**	**Trot VAS**	**Discomfort VAS**	**Trot VAS**	**Discomfort VAS**
1	RIGHT	3.0	2.6	RIGHT	40	21.1	37.9	31.6
2	RIGHT	0.6	7.9	RIGHT	38.9	34.7	6.3	2.1
3	RIGHT	5.1	9.0	RIGHT	35.8	12.6	8.4	13.7
4	RIGHT	1.3	1.8	RIGHT	56.8	27.4	0.0	0.0
5	LEFT	11.5	5.3	LEFT	32.6	1.1	74.7	68.4
6	LEFT	12.5	6.0	LEFT	56.8	17.9	50.5	52.6
7	RIGHT	1.4	13.5	RIGHT	75.8	50.5	32.6	46.3
8	RIGHT	0.8	6.9	RIGHT	62.1	0.0	27.4	84.2
9	LEFT	2.1	8.5	LEFT	24.2	14.7	89.5	77.9
10	RIGHT	0.7	5.4	RIGHT	54.7	0.0	68.4	63.2
11	LEFT	27.3	15.3	LEFT	56.8	49.5	8.4	34.7
12	LEFT	9.1	8.5	LEFT	74.7	45.3	42.1	20.0
13	RIGHT	3.3	2.6	RIGHT	52.6	0.0	36.8	46.3
14	RIGHT	7.9	6.8	RIGHT	23.2	0.0	35.8	55.8
15	RIGHT	0.9	4.7	RIGHT	38.9	34.7	0.0	74.7
16	RIGHT	4.7	5.0	RIGHT	29.5	15.8	25.3	38.9
17	LEFT	3.2	1.3	LEFT	52.6	13.7	13.7	11.6
18	RIGHT	8.0	1.3	RIGHT	44.2	0.0	32.6	13.7
19	LEFT	0.9	0.6	LEFT	45.3	16.8	29.5	12.6
20	RIGHT	3.2	0.2	RIGHT	44.2	0.0	0.0	0.0
21	RIGHT	6.4	4.1	RIGHT	54.7	18.9	52.6	96.8
22	LEFT	4.1	5.7	LEFT	52.6	12.6	11.6	23.2
23	LEFT	5.1	2.8	LEFT	41.1	21.1	50.5	76.8
24	LEFT	5.8	11.9	LEFT	52.6	0.0	43.2	0.0
25	RIGHT	2.5	4.6	RIGHT	83.2	56.8	30.5	12.6
26	LEFT	6.2	1.4	LEFT	58.9	36.8	32.6	69.5

Table 8: A table to show the data produced by all three assessors for predominant lame limb; lameness severity scores and discomfort severity scores for hindlimb lameness.

11.3.3.2 Correlation of severity of lameness and horse discomfort

Owner and Veterinary surgeon

The VAS scores of both the owner and veterinary surgeons' lameness severity assessment showed a weak correlation for hindlimb (r= 0.39, p= 0.04) lameness (Table 9, Figure 12A). There was a strong positive correlation between the owner and veterinary surgeon's VAS scores of horse discomfort for forelimbs only (r= 0.61, p= 0.01) (Table 10, Figure 12B). When the veterinary surgeons lameness severity VAS score was compared with the owners discomfort VAS score, there was a strong correlation for forelimb lameness only (r= 0.63, p= 0.01) (Table 11, Figure 12C).

Owner and Lameness Locator

The VAS score of the owners' assessment of lameness severity compared with the Lameness Locator quantification of lameness severity (VS) did not identify a significant correlation between the objective and subjective severity scores. When the owners' assessment of horse discomfort was compared with the VS, there was a strong correlation for forelimb lameness only (r= 0.62, p= 0.01) (Table 11, Figure 13).

Veterinary Surgeon and Lameness Locator

The VAS score of the veterinary surgeon's assessment of lameness severity showed a strong correlation with the Lameness Locator (VS) for forelimb lameness only (r= 0.7, p= 0.003). Hindlimb lameness severity scores did not show a significant correlation (Table 9, Figure 14).

Forelimb lameness			
Assessor comparison: lameness severity	**Spearman's rank correlation coefficient**	**P- Value**	**Descriptive correlation**
Owner- Veterinary Surgeon	0.29	0.27	weak
Owner- Lameness Locator (VS)	0.24	0.37	weak
Veterinary Surgeon- Lameness Locator (VS)	0.7	0.003	strong

Hindlimb lameness			
Assessor comparison: lameness severity	**Spearman's rank correlation coefficient**	**P- Value**	**Descriptive correlation**
Owner- Veterinary Surgeon	0.39	0.04	weak
Owner- Lameness Locator (PDMax)	-0.13	0.5	very weak
Owner- Lameness Locator (PDMin)	-0.22	0.28	weak
Veterinary Surgeon- Lameness Locator (PDMax)	0.13	0.5	very weak
Veterinary Surgeon- Lameness Locator (PDMin)	0.24	0.23	weak

Table 9: Forelimb and hindlimb results tables to show the Spearman's coefficient of correlation and the associated p-value for each of the three methods of assessment in relation to each other according to severity of lameness

Forelimb lameness			
Assessor comparison: discomfort severity	**Spearman's rank correlation coefficient**	**P- Value**	**Descriptive correlation**
Owner- Veterinary Surgeon	0.61	0.01	strong
Owner- Lameness Locator (VS)	0.62	0.01	strong
Veterinary Surgeon- Lameness Locator (VS)	0.45	0.08	moderate

Hindlimb lameness			
Assessor comparison: discomfort severity	**Spearman's rank correlation coefficient**	**P- Value**	**Descriptive correlation**
Owner- Veterinary Surgeon	-0.33	0.09	weak
Owner- Lameness Locator (PDMax)	0.03	0.87	very weak
Owner- Lameness Locator (PDMin)	0	0.99	very weak
Veterinary Surgeon- Lameness Locator (PDMax)	-0.2	0.31	weak
Veterinary Surgeon- Lameness Locator (PDMin)	-0.17	0.38	very weak

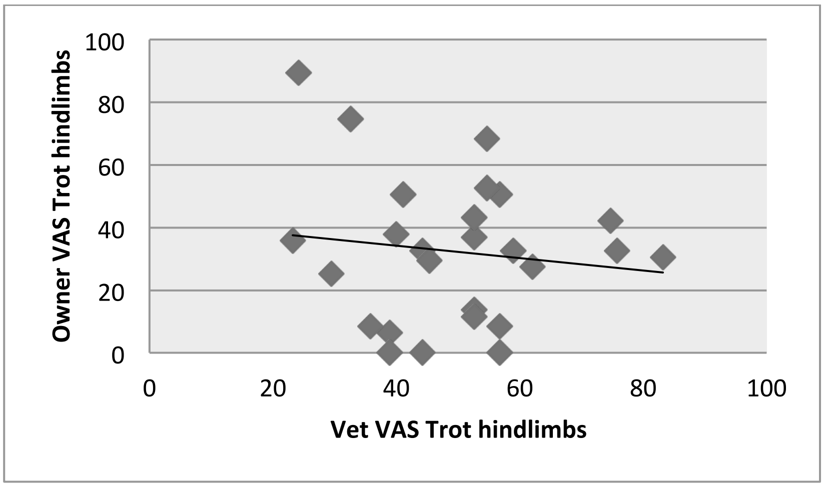
Table 10: Forelimb and hindlimb results tables to show Spearman's coefficient of correlation and the associated p- value for each of the three methods in relation to each other according to severity of discomfort

Forelimb lameness			
Assessor comparison: owner discomfort severity vs veterinary surgeon and LL lameness severity	**Spearman's rank correlation coefficient**	**P- Value**	**Descriptive correlation**
Owner- Veterinary Surgeon	0.63	0.01	strong
Owner- Lameness Locator (VS)	0.62	0.01	strong

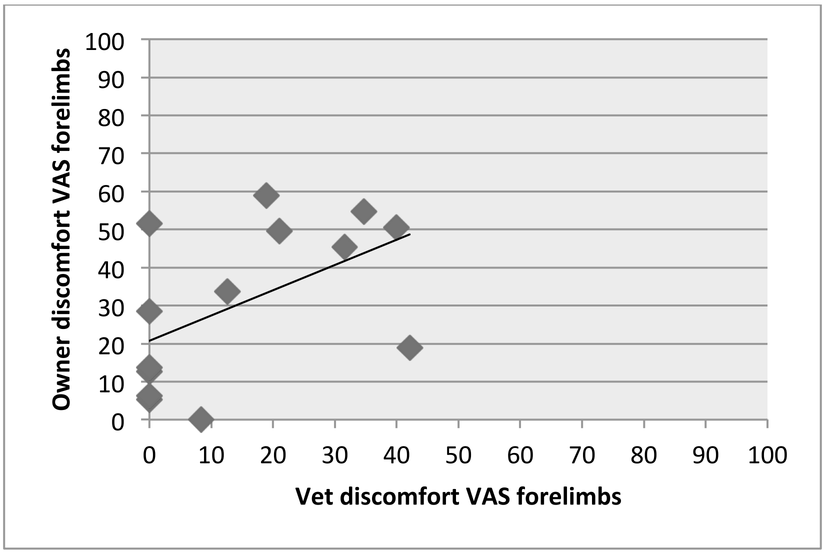
Hindlimb lameness			
Assessor comparison: owner discomfort severity vs veterinary surgeon and LL lameness severity	**Spearman's rank correlation coefficient**	**P- Value**	**Descriptive correlation**
Owner- Veterinary Surgeon	0.04	0.85	very weak
Owner- Lameness Locator (PDMax)	0.03	0.87	very weak
Owner- Lameness Locator (PDMin)	0	0.99	very weak

Table 11: Forelimb and hindlimb results tables to show the Spearman's coefficient of correlation and the associated p-value for each of the three methods of assessment to compare the lameness severity scores for the veterinary surgeon and the Lameness Locator, with the owners severity score of discomfort.

A



B



C

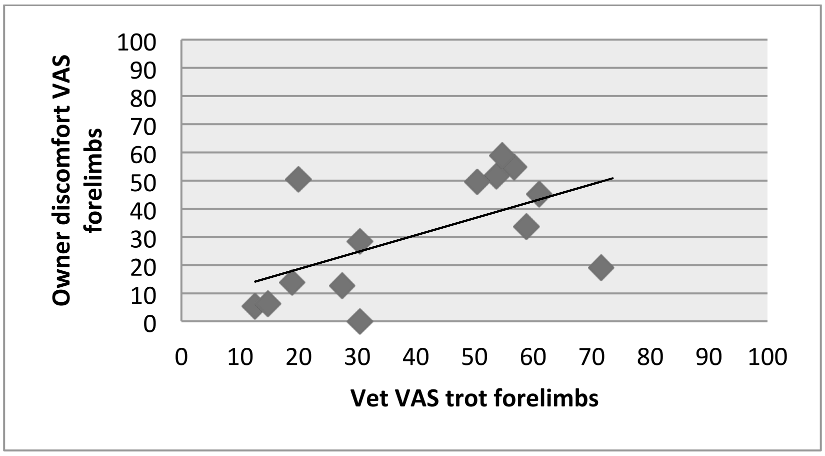


Figure 12 (A, B,C): Scatter plots to show the relationship between owner and veterinary surgeon's severity scoring of lameness and horse discomfort

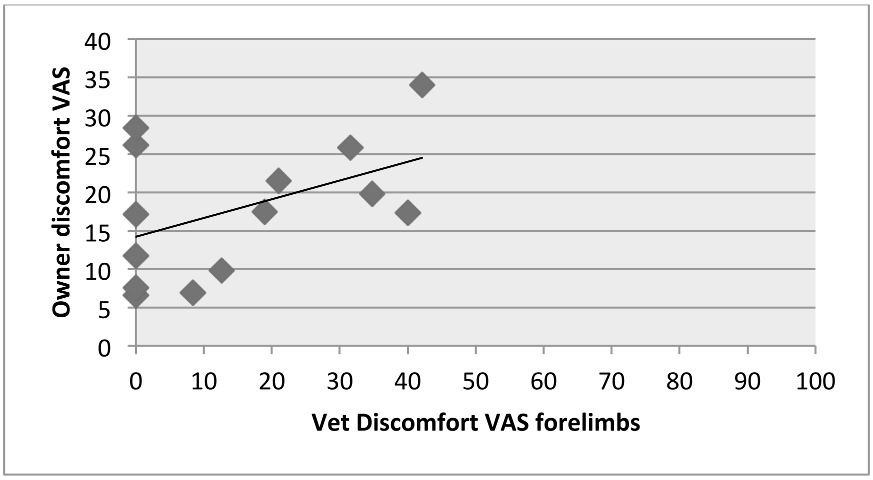


Figure 13: Scatter plots to show the relationship between owner's scoring of lameness severity and discomfort in comparison with the Lameness Locator

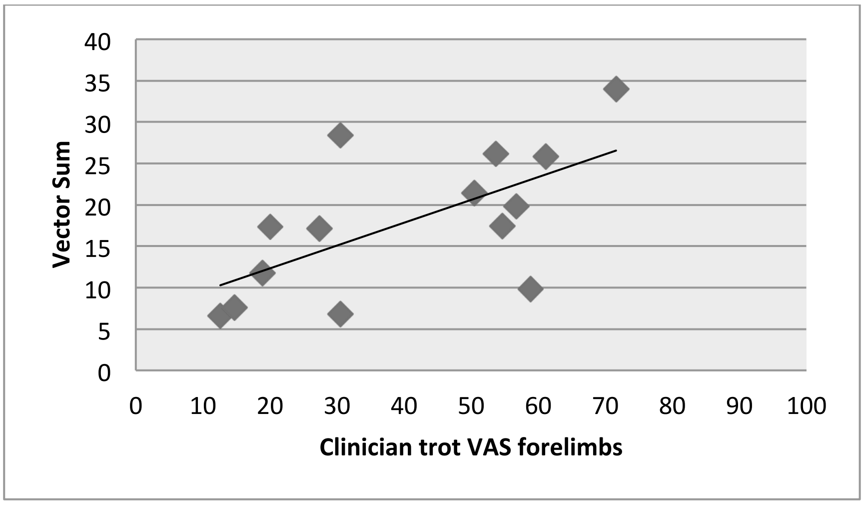


Figure 14: Scatter plots to show the relationship between veterinary surgeon's scoring of lameness severity and discomfort in comparison with the Lameness Locator

11.3.3.3 Agreement between subjective assessors

Bland Altman plots of agreement were carried out between subjective lameness severity and discomfort VAS scoring. Lameness Locator data was not included in this analysis due to the differing scale of severity. The VAS scores of both the veterinary surgeon and horse owner were examined in 3 combinations- lameness severity VAS score of both assessors; discomfort severity score of both assessors; and finally the lameness severity VAS score of the veterinary surgeon and the discomfort VAS score of the horse owner. The graphs below demonstrate the relationship between the difference between the clinician and owner VAS scores in relation to the mean of both (figure 15). This identified that generally owner discomfort severity scores were less than veterinary surgeon's lameness severity scores, and proportional bias existed between assessors i.e. as the lameness increased the level of agreement improved.

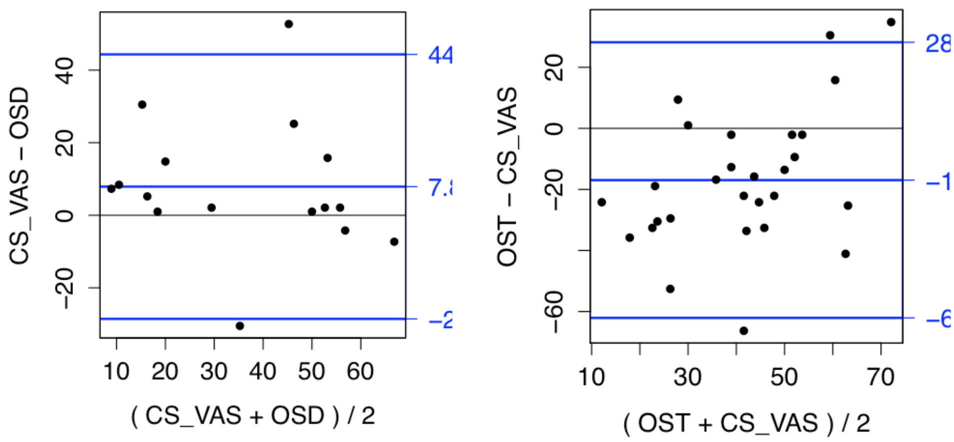


Figure 15: Bland- Altman plots showing agreement between the two subjective assessors with regards to lameness and discomfort severity scores. Plot on left shows the average VAS score plotted against the difference between the Clinician lameness VAS score (CS_VAS) and Owner discomfort VAS score (OSD). The plot on the right shows the average VAS score plotted against the difference between the Owner lameness VAS score (OST) and the Clinician lameness VAS score (CS_VAS).

11.4 Discussion

This study has demonstrated the difference in lameness evaluation between three assessors, where the 'untrained' assessor was the experienced horse owner in comparison with the veterinary surgeon and the objective Lameness Locator®. Previous studies have examined the differing opinions of trained and untrained professionals, however the untrained but experienced individual has not previously been investigated. The importance of reliable and validated subjective lameness scoring is becoming more recognised due to the development and increasing use of objective lameness assessment (Quinn et al. 2007). Increased familiarity with the equine orthopaedic examination means that a single examiner will develop their individual technique of clinical examination, assessing and recording the severity of lameness. Despite the existence of multiple lameness grading scales, the inherent subjectivity of an individual's orthopaedic assessment results in variability between assessors, even those who have equal specialist experience. Likewise, an untrained person has a unique appreciation for gait assessment, particularly in an animal they are familiar with. Therefore we can deduce that the trained individual had a specific familiarity with the orthopaedic examination, and the untrained person had a specific familiarity with his or her own horse presenting for an orthopaedic examination. The appreciation of equine lameness is likely to be different for these two groups, however both are equally important for the recognition and treatment of equine lameness.

This study was designed using VAS scoring systems for both subjective assessors due to the comparison of continuous data sets with the Lameness Locator output, the ease of use for untrained individuals and to provide a means of assessing other subjective information on the same scale i.e. discomfort and lameness severity. Visual analogue scales are widely used in human pain scoring systems for individuals of wide ranging age, cognitive ability and medical complaints. In the study population it has been demonstrated that a horse owner's interpretation of lameness is most accurate as an overall estimation of discomfort. The owner's appreciation of lameness severity was more strongly correlated with both the veterinary surgeon and the Lameness Locator when the VAS score descriptor was changed from 'lameness' to 'discomfort'. This is an interesting finding because the owner was asked to evaluate both characteristics during the same lameness evaluation, under the same conditions and therefore the discrepancy in correlation coefficients represents a true difference of owners' opinion. This finding indicates that the owner's appreciation of lameness severity was most accurate as a measure of discomfort.

The questionnaire completed by horse owners supports this finding because of the free text descriptions recorded by owners. Less than half (47%) of the descriptions recorded by the owner population included ‘lameness’ as the primary reason for seeking veterinary attention. Although this was most frequently recorded in comparison to the other descriptors, ‘lameness’ may not have been included in all cases because the horse presented with different clinical signs; the lameness was low- grade; the lameness involved more than one limb; or possibly because some owners will naturally be less experienced in recognising signs of lameness.

The change in gait which is most appreciated by the observer is an important point to consider. Analysis of the data presented here provides evidence to show that there was better correlation between the orthopaedic specialist observer’s assessment of lameness and the gold standard objective assessment than the untrained observer (Tables 7, 8, 9). These findings are consistent with studies comparing trained versus untrained observers described in the introduction of this chapter (Fuller et al. 2006; Keegan et al. 2010). There were higher and significant correlation coefficients for the trained observer than the untrained observer when compared to the objective data. This was not considered surprising and supports previous studies that showed experienced clinicians have more sensitive and repeatable lameness scores in comparison to inexperienced students (Arkell et al. 2006). However, when the objective data was compared with the owner discomfort severity score, the correlation was considerably stronger. In addition, when the veterinary surgeon’s discomfort severity score was compared with the objective data the correlation was not significant. This finding indicates that there is an alteration in how an individual examines a lame horse when the descriptor of the VAS line is changed. The Bland-Altman plots showing agreement between subjective assessors identified that the veterinary surgeon assigned a higher severity score for lameness examination than did the owner for discomfort score (Figure 15).

The use of the VAS scoring method of lameness assessment for subjective assessors was a novel approach in comparison to other equine- based studies. There was concern of VAS scoring being an inappropriate method of recording for an experienced clinician, most familiar with the use of a numeric and descriptive grading scale. However, in this study, the clinician VAS score was strongly correlated with the Lameness Locator severity scoring (Tables 7, 8). In addition, results of a pilot study carried out using some of the data from this study showed that there was a significant correlation between VAS scores and objective measurement of head ($r=0.45$, $p<0.001$) and pelvic asymmetry ($r=0.27$, $p=0.04$) in 58 horses with naturally occurring clinical lameness (Norton et al, 2015). Therefore, we concluded that VAS scores provide a subjective method of assessing lameness on a continuous scale that is significantly correlated with objective measurements.

All of the horses in this study presented with mild- moderate, consistent predominant forelimb or hindlimb lameness. Typically, this represents the more difficult degree of lameness to assess subjectively, supported by studies describing poor inter- and intra- assessor agreement for low-grade lameness (Keegan et al. 1998; McCracken et al. 2012). Analysis of the data presented provides new evidence to support this statement due to the introduction of objective lameness assessment as a comparison. This data set identifies a strong correlation between the subjective trained assessor and the objective measure for forelimb lameness, and a surprisingly weak correlation for hindlimb lameness (Table 9). This finding suggests that outside the extremes of lameness the correlation between visual observation of gait and actual vertical pelvic asymmetry is weak. The result of poor correlation coefficients for hindlimb lameness compared to forelimb lameness may explained by the fact that hindlimb lameness is generally regarded as more difficult to detect than forelimb lameness due to more subtle changes in vertical displacement of the pelvis than the head. In addition, the subtleties of lameness detection may have been further complicated by low- grade bilateral hindlimb lameness, meaning the clinician was likely to give a lower VAS score than the objective assessment.

There was, however, slightly better agreement in the choice of predominantly lame limb for hindlimb than in forelimb lameness between the veterinary surgeon and Lameness Locator. The various reasons for this may include the possibility of human error; and that horses with low-grade bilateral forelimb lameness showed slightly more vertical displacement of the head for one forelimb than the other, which differed from the opinion of the clinician. As hindlimb lameness is generally considered to be more difficult to detect, there is also the possibility that the hindlimb lameness cases were more severely lame than the forelimb cases. This comparison is outwith the realms of this study and therefore has not been carried out. In light of the fact that more of the forelimb cases were removed due to lack of limb agreement, we should also consider that the remaining lameness cases were more severely or unilaterally lame and therefore there was a stronger correlation between subjective and objective comparisons. A study carried out assessing experimentally induced lameness in dogs to compare subjective and objective gait analysis identified a noticeable decrease in correlations when both the normal and non- weight bearing trials were omitted from the analysis (Waxman et al. 2008). As the current study was based on clinical lameness cases in a referral setting, we must take into consideration that many of the horses typically present with chronic, multi- limb lameness. We focussed on a single limb for the purposes of this study and therefore it is easy to forget that the clinician's severity scores for both lameness and discomfort were likely to have been influenced by other factors such as general gait of the horse, other lame limbs and clinical findings such as foot balance.

In this study population it has been demonstrated that there is best correlation for subjective and objective methods of lameness detection between veterinary surgeon lameness severity and owners' discomfort severity scores for forelimb lameness only. The generally weak correlations between all three datasets for hindlimb lameness despite the good agreement in predominant lame limb may indicate that there is an inherent discrepancy in severity scoring between subjective and objective means of assessment. The Lameness Locator has been shown to have better sensitivity at detecting low- grade clinically- induced lameness in forelimbs than experienced clinicians (McCracken et al. 2012) in 58% of lameness examinations, therefore we might expect the same to be true in hindlimbs. The VAS scoring system would also highlight the discrepancy between the subjective and objective assessors because of the continuous nature of the data recorded versus numeric rating scales. In any case, the lamest limb was detected in the majority of examinations, and the severity score given acted as a baseline for lameness work- up. The use of the VAS scoring system could be further investigated using flexion tests and diagnostic anaesthesia as a means of detecting changes in the subjective assessment of lameness in comparison to the objective assessment.

The limitations of this study need to be considered, and these include the variations in data collection due to the behaviour of the horses despite having a minimum number of strides per data collection and allowing the clinician to carry out the lameness examination as they saw fit; the variation between observers and the possibility of human error when evaluating and recording the severity of lameness; the presence of only one observer per horse in each category (trained and untrained) which may allow for increased human error and decreased sensitivity of the study; and finally the range of breeds and therefore gaits of the horses used in this study. By carrying out a clinical study of naturally occurring lameness, using horses and owners who were unaware of the study prior to arrival we have been unable to control for body size and condition of the horse, cause of lameness and level of experience of owner.

11.5 Conclusions

The data presented here represents the first analysis of owner evaluation of lameness in comparison with that of a veterinary surgeon and the Lameness Locator in naturally occurring lameness, assessed in a clinical setting. The horses were a sub- set of the equine population of the UK that typically present to referral hospitals for investigation of low- moderate grade lameness or poor performance, and therefore are representative of clinical scenarios. The comparisons made between the owner and veterinary surgeon highlight the discrepancy between trained and untrained individuals' assessment of lameness. The comparisons made between the subjective assessors and the gold- standard objective method of assessment highlights the differing perceptions of equine lameness.

Communication between veterinary surgeon and horse owner may be improved based on the findings of this research. The correlations of owner perceptions of lameness have provided strong evidence to suggest that being familiar with how an individual animal moves is as sensitive as the routine lameness examination through the eyes of a trained individual with no prior knowledge of a particular horse. The important relationship between horse owner and veterinary surgeon has been identified and allows us as veterinary surgeons to feel more confident in allowing owners to monitor a horse's comfort levels following treatment for an orthopaedic complaint.

Further expansion of the study to determine why there is such poor correlation between untrained subjective assessors, trained subjective assessors and objective assessment of hindlimb lameness would be of use for hindlimb lameness. Collation of all clinical data taken at the time of the lameness assessment, including details of multi- limb lameness, gait abnormalities and resulting diagnoses would further investigate potential causes of differing lameness severities with objective assessment.

12 Chapter five: A summary of the identification and impact of equine lameness on equine owners in the UK

The findings of this research detail and quantify the impact of an episode of equine lameness on both the horse and the owner. With the use of both the hospital setting and clinical cases, and an online survey, we have gained a significant amount of knowledge regarding the equine owner population and horse population of the UK. Prior to production of a large- scale national survey to obtain information on the daily costs associated with horse ownership, there was very little available demographic data or quantification of basic horse ownership and the factors, which influence expenditure. Likewise, until now there have been few studies produced which describe owners perceptions of equine lameness, nor those which quantify and test these against experienced clinicians and the newly- considered gold standard apparatus for objective measurement of equine lameness.

The first half of the study also investigated the duration of time a horse was not in use following an episode of lameness, and importantly whether it was able to return to its prior level of work. The time between onset and investigation of an episode of lameness has not been a focus of this research, however in the prospective clinical study we have identified the period of time prior to referral to a specialist centre. Combining the two parts of this research, we could therefore estimate the financial loss to the owner by number of days lost and daily cost of ownership. In many cases this is a considerable period of time, which is frequently overlooked when considering treatment options and timescales of rehabilitation following an episode of lameness. Future developments of an annual survey that focuses entirely on the lame horse, including the financial outlay and timing of lameness investigation could provide important data trends, which are unavailable in the current literature. Having more detailed lameness- related data, potentially available on an annual basis could contribute to an increasing body of information currently available for general equine health.

This research demonstrates the importance of the owner in detection and monitoring of lameness. The importance of appreciation of differing methods of lameness detection has also been highlighted; both from a perception of lameness between a trained and an experienced individual, and also regarding lameness scales and methods of recording data. The findings in this Masters Thesis are representative of lameness reported by actual horse owners and clinical signs observed as in clinical cases as all horses in the study had naturally occurring lameness.

We consider the horse owners in this study to be representative of the general horse population. Owner assessments of “lameness” correlated weakly with veterinary and the Lameness Locator assessments for all limbs. However, when owners were asked to assess the severity of their horse’s “discomfort” then the correlation with the veterinary and the Lameness Locator assessments for lameness was much stronger for the forelimbs only. This raises an important issue that whilst recognising that there is something wrong with their horse, and that it may be experiencing “discomfort”, many owners may not see that as “lameness” as such. In addition, in cases of low- level or multi- limb lameness, owners did not elect for immediate referral for further investigation. In the second part of this research, we see that although the majority of horses were referred in less that 3 months, almost a third of horses had shown signs of lameness for over 3 months before a specialist opinion was sought. In these cases, it is unclear as to whether owners appreciated the fact that some degree of lameness is very common in horses and therefore referral was not elected for until the degree of lameness became performance limiting or whether the owners simply did not recognize the presence of lameness. This was supported by the fact that owners identified “lameness” as the primary reason for their referral to the hospital in only 47% of cases. It may well therefore be that the 71% incidence of “lameness” in the last 12 months recorded in the online survey in the first part of this thesis is significantly underestimating the true prevalence of lameness in the pleasure horse population in Great Britain.

The discrepancy highlighted between trained and untrained individuals during lameness assessment is enough evidence to support further training of equine owners, in a more formal way. In addition to training equine owners, veterinary undergraduate students or junior veterinary surgeons may benefit from a more focussed approach to development of the ability to assess lameness. Online resources such as the ‘lameness trainer’ currently exist, however there is room for development of other training tools, and methods to assess improvement in lameness detection. Improved understanding of equine lameness and wider education of the importance of earlier investigation could result in earlier detection times, earlier investigation and therefore earlier intervention. This research also shows that less time spent out of work is a positive predictor for return to previous use and therefore both horse and owner benefit from a more proactive approach to equine lameness. The positive effect of proactivity on equine welfare is of utmost importance and therefore increasing awareness of how widespread equine lameness is, and how we can help to reduce negative outcomes should be an important focus for continued work in this area.

13 Appendices (Please see attached as separate documents)

13.1 Survey study

13.1.1 Letter of introduction of online survey

13.1.2 Online survey

13.2 Lameness study

13.2.1 Pilot study owner lameness questionnaire

13.2.2 Owner lameness questionnaire

13.2.3 Clinician VAS score record

14 List of suppliers

14.1 **Survey Study**

14.1.1 Survey Monkey: https://www.surveymonkey.co.uk

14.1.2 Software used for analysis

14.1.3 Microsoft Excel for Mac 2011, 2010 Microsoft Corporation. Version 14.6.7 (160722). Product ID 03325-051-0147513-02938.

14.2 Lameness study

14.2.1 Lameness Locator: Equinosis, 1141 South 7th Street, St. Louis MO 63104, (877) 881 8002. Https://www.equinosis.com

14.2.2 Vet Wrap: 7.5cm cohesive bandaging material, Dunlops

14.2.3 Duct tape: 5cm pressure-sensitive tape, polyethylene coated

14.2.4 Software used for analysis: R Project for statistical computing, The R Foundation, RStudio. Https://www.r-project.org.

15 List of references

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