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Cross-sectional study of the prevalence of and risk factors for hoof disorders in horses in The Netherlands

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ABSTRACT

Information is scarce on the prevalence of hoof disorders in horses. In this study, we examined the prevalence of and risk factors for hoof disorders in a population of horses in The Netherlands. In a group of 942 randomly selected horses, hoof health was scored during regular foot trimming (one horse/farm). Hooves were assessed for the occurrence of one of 12 hoof disorders by a group of 21 certified farriers in two periods i.e. winter and summer of 2015.

The mean age of the group of horses was 11.2 ± 5.6 years. They were mainly used for recreation (28.2%), dressage (26.8%), other disciplines (such as carriage driving and breeding) (18.7%), showjumping (17.6%) or combinations of these activities (8.6%). The horse farms studied were evenly distributed throughout the country. The horses were housed on different types of bedding, including straw (51.0%), shavings (17.5%), flax (16.1%) or other materials (11.0%), or were kept at pasture (4.4%).

In 85% of the horses, at least one hoof disorder was observed during regular foot trimming. Most of the lesions were mild. The most frequently diagnosed hoof disorders were: thrush (T; 45.0%); superficial hoof wall cracks (SHWC; 30.4%); growth rings (GR; 26.3%); and sole bruises (SB; 24.7%). Less frequently observed hoof disorders included: perforating hoof wall cracks (PHWC; 16.4%); white line disease (WLD; 17.8%); and white line widening (WLW; 11.8%). Horizontal hoof cracks (5.2%), chronic laminitis (3.9%), quarter cracks (2.7%), keratoma (1.8%) and frog cancer (1.0%) were less frequently observed.

Factors significantly associated with the occurrence of thrush comprised a wet stable floor (OR 1.6 and 2.9, for somewhat wet to wet respectively, compared to dry), the use of straw as bedding (OR = 1.5, compared to flax), the housing strategy (e.g. permanent housing in contrast to permanent pasturing) (OR = 1.7) and poor horn quality (OR = 3.4). A higher prevalence of WLD was associated with less frequent hoof picking (OR = 2.1 if performed weekly instead of daily), the use of flax bedding (OR = 2.1, compared to straw) and poor horn quality (OR = 8.1). A higher prevalence of SB was observed in horses used for multiple disciplines (OR = 3.5, compared to dressage), with white-coloured hooves (OR = 5.0, compared to black hooves), with longer intervals between trimming sessions (OR = 4.8 in case of 8–10 weeks compared to weekly) and with poor horn quality (OR = 5.4). A higher prevalence of WLW was observed in older horses (OR = 15.5 for horses >19 years, compared to <5 years), in those with longer intervals between trimming sessions (OR = 1.8 in case of 8–10 weeks compared to weekly), and in certain breeds (OR = 3.2 for Friesian horses, 2.9 for Welsh ponies and 13.1 for Shetland ponies, all compared to Dutch Warmblood).

In conclusion, although most of the hoof disorders identified were only in a mild stage, still an unexpectedly high prevalence of hoof disorders was observed during regular hoof trimming. Analysis of the data showed that some parameters, such as the use of flax bedding, may be protective for certain hoof disorders but a risk factor for others. This study provides useful guidelines for monitoring hoof health, reducing lameness and optimizing equine welfare.

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1. Introduction

Foot disorders are considered the most common cause of lameness in horses (Floyd and Mansmann, 2007). However, aside from investigations on the diseased pododerma of the hoof (i.e. laminitis; Eps van et al., 2010; de Laat et al., 2016) and the septic components associated with white line disease (WLD; Apprich et al., 2010; Redding and O'Grady, 2012), recent research on the prevalence of and risk factors for hoof disorders in horses is scarce. Hoof disorders can cause lameness and lead to a true dysfunction of a horse, decreased welfare, economic losses for its owners and, eventually, a reduction in its durability (Lloyd and Kaneene, 1997; Floyd and Mansmann, 2007; Collins et al., 2010; Ireland et al., 2013). A better understanding of the various causes of hoof disorders may contribute to a wider appreciation of the possible treatment and management options (Moyer, 2003). Some hoof disorders may be caused by a single incident (e.g. a nail in the sole of the hoof), but most cases are considered multifactorial and, ultimately, of management origin (Bergsten, 2003; Hunt and Wharton, 2010).

In this study, we evaluated the prevalence of the most common hoof disorders in horses in The Netherlands and assessed the risk factors associated with their occurrence.

2. Materials and methods

2.1. Horses

A sample size of 500 horses was estimated to statistically evaluate the prevalence of several hoof disorders with 95% confidence and a maximum error of 2% (WIN EPISCOPE 2.0; Thrusfield et al., 2001). For this sample size calculation an expected prevalence of 50%, which resulted in the largest required sample size, was assumed because there was no prior information available. At the start of the study, farriers were requested to select clinically healthy horses at random on a farm where trimming was done on a regular basis, i.e. at least 4 times/year. The farriers were advised to select for example the first or the last horse offered at a particular moment or to use a random selection app on their mobile phone. This app was strongly advised and helpful for the farrier to optimize the randomisation for the selection of the horse, but it was not checked how the selection of horses was performed. The inclusion criteria were age (older than 1 year) and that the horse's hooves should have been trimmed by the farrier at least twice before the study. Participation was agreed by the owner; owners could choose not to participate but no refusals were reported by the farriers.

2.2. Farriers and data collection

Considering that hoof disorders may not be distributed equally across the country, perhaps depending on the type of soil in each province and/or on the density of horse farms, a group of qualified farriers (n = 21) located across the country were approached to record hoof disorders during their regular hoof-trimming sessions. Farriers were selected based upon their qualification, experience, working area and willingness to participate, in collaboration with the Board of the Netherlands Association of Certified Farriers. The selected farriers were either related part-time to a veterinary practice (n = 10) or were private consultants (n = 11). The farriers were asked to randomly select and score 25 horses from 25 different locations during the period in which the horses were kept stabled (February–March 2015) and 25 horses during the period in which the horses were pastured (June–July 2015) That means that the farrier determined on forehand e.g. the horse offered on Monday morning as the first horse or last horse is chosen for recording. Records made during regular hoof-trimming sessions were combined with a survey of the exact location of the stables and its housing and management factors (Supplementary materials, Appendix A). Part of the information was gathered through the observations of the farriers (location, frequency of trimming, quality and colour of the hoof, humidity of stable bedding). Information that could not exactly be known by the farrier, was filled in with help of the horse owner (e.g. age of the horse, pasturing frequency and hours/day, frequency of hoof picking). The soil type (source Alterra, Wageningen, the Netherlands) was based on the four digit postal code area in which the horse was located. Information about the presence or absence of 12 hoof disorders was collected on the basis of visual inspection and smell. Definitions (Supplementary materials, Appendix B) were presented on a photo card and during the training session. The most severe stage of the lesion in all four hooves determined the final score to be recorded. The disorders that were scored and recorded comprised: thrush (T); superficial hoof wall cracks (SHWC); perforating hoof wall cracks (PHWC); white line disease (WLD); sole bruises (SB); white line widening (WLW); frog cancer; chronic laminitis; keratoma; horizontal hoof cracks; quarter cracks; and growth rings. The photo card depicting the disorders was developed in cooperation with the board of the Netherlands Association of Certified Farriers and the professional farriers of the University Clinic for Horses (UCH) in Utrecht is available at www.gdanimalhealth.com. The farriers were trained in the diagnosis of hoof disorders according to these standards through study and discussion of the photo card and through the live scoring of nine horses, resident at the UCH before the start of data collection. The diagnoses made by the farriers were compared to those on the photo card and discussed with the complete group of farriers. To standardize the diagnosis of less frequently found conditions, the farriers were asked to send photographs of cases with a diagnosis of keratoma or hoof cancer. The latter were discussed by a team of experts before being definitively recorded.

2.3. Data analysis

The disorders were recorded as absent or present. In addition, for the disorders thrush, SHWC and PHWC, WLD, SB and WLW, scores were assigned based on severity (mild, moderate or severe; see Supplementary Table 2). Information on hoof disorders was collected for the individual horses studied and the presence of a disorder was defined as a disorder diagnosed in at least one hoof.

2.4. Statistics

The data from the questionnaire were digitized using the programme NETQ Premium (NetQuestionnaires Nederland BV, 2014). Stata 14® (StataCorp LP, College Station, TX, USA) was used for the validation and analysis of the data. The estimations of prevalence were presented using descriptive statistics such as proportions, together with their confidence intervals. The associations between horse-specific characteristics (i.e. horse/pony, age, hoof quality, sex and breed) or management factors (i.e. purpose, housing, pasture: yes or no, shod: yes or no, only trimmed, hoof picking) and the occurrence of hoof disorders were evaluated using logistic regression models with a logit link function. For each of the hoof disorders evaluated during this study, the prevalence was estimated. For hoof disorders with a prevalence of at least 10%, risk factors were assessed, except grow rings which were considered of minor importance. For these disorders, the specific disorder occurred was included as the dependent variable and the horse-specific characteristics and management variables were included as independent variables. Using univariate analysis techniques, the independent variables were pre-screened based on their potential to be associated with the occurrence of each of the analysed hoof disorders. For each hoof disorder, the variables that were associated (*P*-value

<0.25) with the occurrence of the specific disorder were selected for inclusion in the multivariable model. For each hoof disorder, the best final multivariable model was selected using a stepwise backward selection and elimination method in which, after each round, the variable with the highest overall *P*-value was excluded from the model until all variables had a *P*-value of 0.1 or lower. The optimal model was evaluated using the Akaike information criterion (AIC), where an AIC value closest to zero was deemed the best model (Akaike, 1974) The Hosmer and Lemeshow test was used to evaluate the fit of the final model. Confounders were monitored by the change in the coefficient of a variable after removing another variable from the model. If the change in the estimate exceeded 25%, or 0.1 when the value of the estimate was between −0.4 and 0.4, the variable removed was considered a potential confounder and was re-entered into the model. The robustness of the final model was checked by performing the same procedure with forward stepwise selection and elimination. In the final model, all biologically credible two-way interactions were tested. The amount of variance explained by the final model was represented by the pseudo *R*[2].

3. Results

3.1. Horses and hoof disorders

Information about the presence of hoof disorders and potential associated risk factors was collected from 942 horses (510 in the period of stabling and 432 in the period at pasture).

The participating horses were distributed similar to the horse density in the Netherlands. For example, most participating horses originated from the eastern part of the Netherlands, which has the highest horse density in the Netherlands (Fig. 1).

Owing to the low density of horses and farriers, the northern, western and southern parts of the country were less well represented. Nonetheless, based upon the large region studied and the high number of participating horses, we expected our results to give a good indication of the prevalence of hoof disorders in The Netherlands.

The mean age of the participating horses was 11.2 ± 5.6 years (median: 17, range: 1–37 years). They were used for recreation (28.2%), dressage (26.8%), other disciplines (such as carriage driving and breeding) (18.7%), showjumping (17.6%) or combinations of these activities (8.6%). More than half of the horses were male (6.1% stallions and 50.1% geldings). The horses were kept on different types of bedding, including straw (51.0%), shavings (17.5%) or flax (16.1%), or at pasture (4.4%).

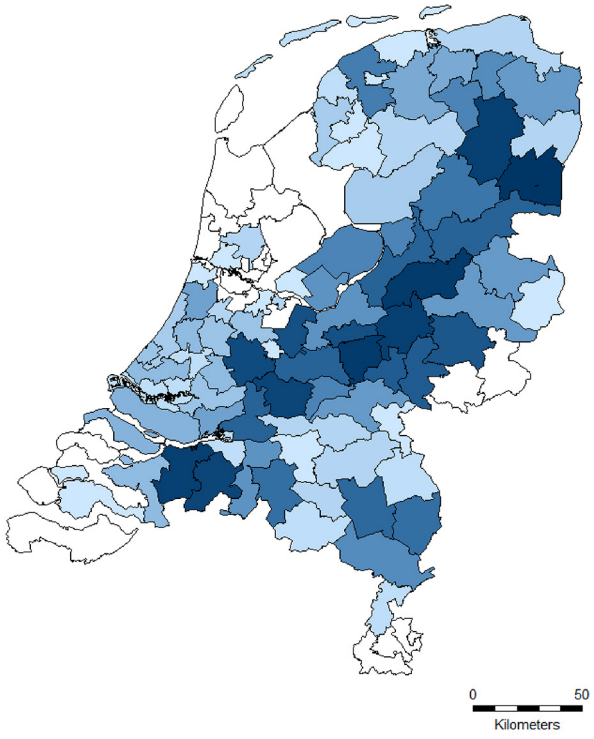

Fig. 1. The geographical distribution of the 942 horses and farms participating in a prevalence and risk factor study on hoof disorders in The Netherlands (2014–2015). The darker regions correspond to higher numbers of participating horses and farms white (0 farms), 1) lighter (= 1–20 farms), 2) light (= 21–40 farms), 3) middle (= 41–60 farms), 4) dark (= 61–80 farms) and 5) darker (= 81–100 farms).

The prevalence of a hoof disorders at the time of regular hoof maintenance was 85%; the majority of hoof disorders were classified as mild (see Fig. 2).

The mean number (±standard deviation [SD]) of disorders per horse was 2.0 ± 1.7 (range 0–10, median 2; see Fig. 3).

Season was included as independent variable in the models, but was not significant in the multivariable model and therefore excluded from the final model.

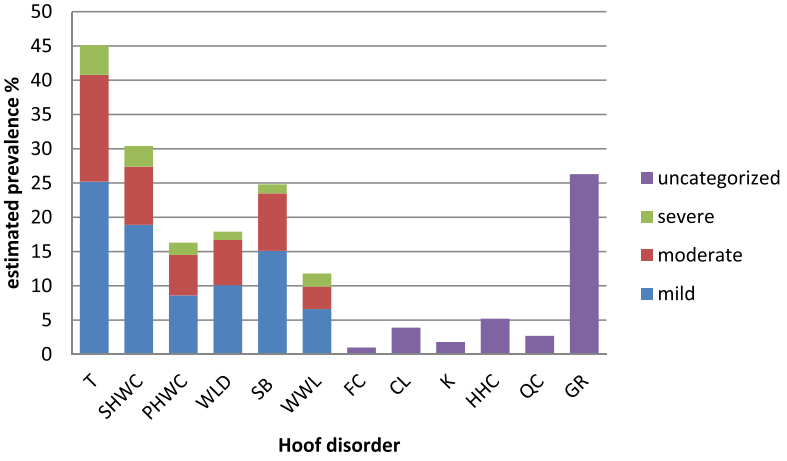

Fig. 2. The estimated prevalence of the different hoof disorders and their grades of severity at the time of regular hoof trimming in a group of 942 horses in The Netherlands (2014, 2015). T = thrush, SHWC = superficial hoof wall crack, PWHC = perforating hoof wall crack, WLD = white line disease, SB = sole bruises, WLW = white line widening, FC = frog cancer, CL = chronic laminitis, K = keratoma, HHC = horizontal hoof cracks, QC = quarter cracks and GR = growth rings; mild: dark, moderate: light, severe: intermediate and 6 lesions were uncategorized.

Table 1
Overview of the lesions found, a short definition and prevalence of the different grades is presented in Table 1. (SHWC = superficial hoof wall cracks; PHWC = perforating hoof wall cracks; WLD = white line disorder; SB = sole bruises; WLW = white line widening, n = 942 randomly selected horses, 2015).

		Prevalence	Distribution of severity		
disorder	description	(%)	Mild (%)	Moderate (%)	Severe (%)
Thrush	Affliction of the frog mostly in the central sulcus	45.0 (n = 424)	55.9 (n = 237)	34.7 (n = 147)	9.4 (n = 40)
SHWC	Superficial (until white line) hoof wall cracks	30.4 (n = 286)	62.2 (n = 178)	28.0 (n = 80)	9.8 (n = 28)
SB	Hemorrhages visible in the sole after superficial trimming	24.7 (n = 233)	61.0 (n = 142)	34.0 (n = 79)	5.2 (n = 5)
WLD	Lesion of the white line	17.8 (n = 168)	56.5 (n = 95)	37.0 (n = 62)	6.5 (n = 11)
PHWC	Perforating (white line) hoof wall cracks	16.4 (n = 154)	52.6 (n = 81)	36.4 (n = 56)	11.0 (n = 17)
WWL	Widening of the white line	11.8 (n = 111)	55.9 (n = 62)	27.9 (n = 31)	16.2 (n = 18)
Gr. Rings	Growth rings visible in the wall	26.3 (n = 248)			
Hor. Hoof cracks	Horizontal hoof crack	5.2 (n = 49)			
Chr. Lamin.	Hoof with clear divergent growth rings and possibly an upturned toe	3.9 (n = 37)			
Quarter craks	Spontaneously appearing cracks in the hoof wall, running from the coronary band, sometimes with blood and not all the way down	2.7 (n = 25)			
Keratoma	Keratin-containing tissue by definition part of a malformated white line, emerging between the hoof wall and the sole	1.8 (n = 17)			
Frog cancer	Smelly yellow or white discolouration with cauliflower-like aspect, not removable without blood loss	1.0 (n = 9)			

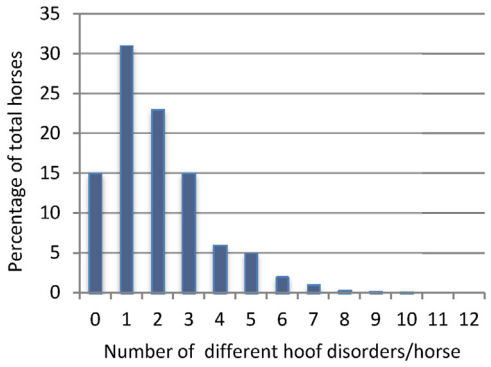

Fig. 3. Schematic overview of the number of different hoof disorders/horse (maximally n = 12) that were found at the time of regular hoof maintenance, as found in a group of (n = 942) participating horses and farms in The Netherlands (2014–2015).

Lesions that were found, with a short definition and prevalence of the different grades is presented in Table 1.

Thrush was the most prevalent hoof disorder (45.0%). Other highly prevalent disorders were SHWC (30.4%), SB (24.7%), WLD (17.8%), PHWC (16.4%), WLW (11.8%) and growth rings (26.3%). Disorders with a low prevalence included horizontal hoof cracks (5.2%), chronic laminitis (3.9%), quarter cracks (2.7%), keratoma (1.8%) and frog cancer (1.0%; Fig. 2).

3.2. Risk factors

Risk factors were estimated for the six main hoof disorders: thrush, SHWC, SB, WLD, PHWC and WLW. The final multivariable model contained a selection of variables that were significantly associated with the different hoof disorders ($P < 0.05$ and $P < 0.01$; Table 2). Confounders were not present. The outcome of the Hosmer–Lemeshow test was not significant for all models evaluated, implying that the logistic model fitted adequately.

3.2.1. Horse factors

Shetland ponies had a risk of SHWC five times lower than Warmblood horses Friesian horses and Welsh and Shetland ponies had a higher risk, respectively, of WLW than Warmblood horses. Black hoof horn was associated with a risk of SB five times lower than white horn; hooves of fair or poor horn quality were associated with a higher risk of all types of hoof disorder than those of good quality. Advanced age was associated with a greater risk of WLW.

3.2.2. Management factors

Picking out hooves was associated with the occurrence of PHWC and WLD. Picking out less than once a week was associated with a higher risk of both lesions than picking out on a daily basis. Horses whose hooves were never picked out were at higher risk of PHWC. Reasonably dry and humid bedding were associated with a higher risk of thrush than dry bedding. Flax, mixed shavings and other bedding materials were associated with a lower risk of thrush than straw bedding. Straw bedding was associated with a lower risk of WLD than flax and shavings, whereas other bedding types were associated with a higher risk of SB than straw. Any pasturing (≥2 h/day vs. no pasturing) was associated with a lower risk of thrush and a higher risk of SHWC. Limited access to the paddock (for 8 h) or no access were associated with a higher risk of WLD. Intervals between trimming longer than 6 weeks were associated with a higher risk of SB and WLW. Shoeing of the hooves was associated with a lower risk of SHWC compared with bare feet and being completely shod was associated with a lower risk of PHWC. Sand and turf were associated with a higher risk of SHWC than clay. Showjumping, driving and combinations of different disciplines were associated with a higher risk of WLD than dressage (see Table 2). No variation in the way of application of shoeing (cold vs. warm) on the risks of hoof horn lesions was found. The variation in the questionnaire completion in Table 2 has to do with the absence of the owners in a limited no. of visits and if the person who assisted the farrier did not know that also, the answers on the questions in the survey remained open.

4. Discussion

In this study, we evaluated the prevalence of the most common hoof disorders of horses in The Netherlands and identified potential risk factors associated with their prevalence. Our overall aim of this study was to prevent hoof disorders and concurrent lameness and, thus, improve equine welfare. The prevalence of a hoof disorder at the time of regular hoof maintenance was 85%. However, the majority of the lesions observed were mild and the horses were clinically healthy. The fact that we only selected clinically healthy horses, which means “normal” condition and referring to the locomotor

Table 2
Overview of the Odds Ratio's (OR); only significant (P < 0.05) factors are presented and when P < 0.01: estimates were marked with *and 95% CI's interval were included), of variables associated with different hoof disorders at the time of regular hoof trimming in a group of (n = 942) horses in The Netherlands (2015); abbreviations: T = Thrush, SHWC = Superficial Hoof Wall Crack, PWHC = Perforating Hoof Wall Crack, WLD = White Line Disease. SB = Sole Bruises and WLW = White Line Widening.

	Variables	T	SHWC	PHWC	WLD	SB	WLW
	r^2	0.07	0.07	0.07	0.13	0.09	0.19
	No. of observations	912	918	918	877	886	917
Environmental factors							
Breed	Royal Dutch warmblood		Reference				Reference
	Friesian horse		1.6 (0.9–2.8) ns				3.2* (1.5–6.7)
	Welsh pony		0.5 (0.2–1.3) ns				2.9 (1.0–8.4)
	Shetlander		0.2* (0.1–0.6)				13.1* (5.0–34.3)
	Other warmbloods		0.9 (0.5–1.3)ns				1.7 (0.9–3.4)ns
	Draft horses		0.9 (0.5–1.6)ns				1.9 (0.9–3.9)ns
	Other		0.6 (0.2–1.5)ns				2.8 (0.9–8.5)ns
	Missing		0.9 (0.5–1.7)ns				2.1 (0.9–5.0)ns
Picking hooves	Daily			Reference	Reference		
	Weekly			1.7 (1.1–2.8)	1.1 (0.6–1.7) ns		
	Less than once a week			2.8 (1.6–5.0)	2.1 (1.1–3.8)		
	Never			1.5 (0.9–2.5) ns	0.8 (0.5–1.5) ns		
Stable bedding	Dry	Reference					
	Somewhat wet	1.6* (1.2–2.5)					
	Wet	2.9* (1.8–4.8)					
	N.A. (housed outside)	3.8 (0.5–29.9)ns					
Type of Bedding	Straw	Reference			Reference	Reference	
	Flax	0.7 (0.4–1.0)			2.1* (1.2–3.4)	1.3 (0.8-2.0)ns	
	Shavings	0.6* (0.4–0.8)			1.8 (1.1–2.9)	1.4 (0.9-2.2)ns	
	Different	0.4* (0.2–0.7)			1.3 (0.5–3.1) ns	2.7*(1.4–5.1)	
	Combined	0.4* (0.2–0.8)			1.1 (0.4–2.8) ns	1.0 (0.4-2.2)ns	
	N.A. (always outside)	0.2 (0.0–1.7) ns			0.8 (0.2–2.7) ns	0.2 (0.05−1.0)	
Pasturing	No	Reference	Reference				
	Yes	0.6* (0.4–0.8)	1.4 (1.0–2.0)				
Paddock	*24 h*				Reference		
	8 h				10.0 (1.2–84.7)		
	4 h				6.0 (0.7–52.5) ns		
	2 h				4.6 (0.5–39.2) ns		
	No access				9.0 (1.1–71.6)		
Hoof colour	White					Reference	
	Medium					0.6 (0.3−1.1)	
	Black					0.2* (0.1−0.4)	
Horn quality	Good	Reference	Reference	Reference	Reference	Reference	Reference
	Fair	1.7* (1.2–2.2)	2.0* (1.4–2.7)	2.1* (1.4–3.1)	2.5* (1.7–3.8)	1.8* (1.3−2.6)	2.5* (1.5–4.1)
	Poor	3.4* (2.0–6.0)	2.8* (1.6–4.8)	4.3* (2.4–7.8)	8.1* (4.4–15.0)	5.4* (3.0−9.4)	5.3* (2.6–10.8)
Trimming intervals	<6 weeks					Reference	Reference[a]
	6–8 weeks					4.4 (0.9–20.6)	
	8–10 weeks					4.8 (1.0−22.7)	1.8 (1.0–3.0)
	>10 weeks					2.5 (0.5–12.2)ns	2.4* (1.3–4.5)
Shoed	Not shoed		Reference	Reference			
	Only front shod		0.6* (0.4–0.9)	0.7 (0.4–1.1) ns			
	Completely shod		0.4* (0.3–0.6)	0.5* (0.4–0.8)			
Type of soil	Loam		Reference				
	Sand		2.0* (1.2–3.4)				
	Turf		3.2* (1.5–7.2)				
	Clay		1.4 (0.7–2.9)ns				
	Other		1.7 (0.9–3.1)ns				
Purpose	Dressage				Reference		
	Showjumping				1.9 (1.0–3.3)		
	Driving				2.3 (1.0–5.5)		
	Recreation				1.5 (0.8–2.5)ns		
	Pet animal				2.2 (0.8–6.4)ns		
	Breeding				1.6 (0.5–4.5)ns		
	Other				1.7 (0.7–4.3)ns		
	Combinations				3.5* (1.8–7.0)		
Age	<5 years						Reference
	5–10 years						5.2 (0.7–40.3)ns
	10–19 years						10.8 (1.4–80.9)
	>19 years						15.5* (2.0–22.5)
	Not registered						9.4 (1.0–85.2)

[a] The trimming interval of <6 weeks and 6–8 weeks are combined in one category due to low numbers of observations.

apparatus not known or visible disturbances, may have resulted in an underestimation of the true prevalence. However, presuming only very low numbers of lame horses, we assume that this underestimation will be limited. According to the cross-sectional design, this results provide a good estimation of the prevalence in a population of clinically healthy horses. However, we have only information about horses that are regularly trimmed by farriers, which are assumed to have less hoof disorders as compared to horses of which the hooves are never trimmed. Therefore, again and said before the prevalence found in this study might be a slight underestimation of the true prevalence.

The mean number of disorders per horse was 2.0 and most horses exhibited one or two hoof disorders (31.0% and 23.0%, respectively). The mean age of the horses in our study was 11.2 years. Nonetheless, the mean age of the total horse population in The Netherlands is unknown but in a previous epidemiological survey in sport horses in The Netherlands, a mean age (±SD) of 7.1 ± 3.2 years was recorded (Sloet van Oldruitenborgh-Oosterbaan et al., 2010). The fact that our study population was somewhat older may have been influenced by our inclusion criteria: we enrolled horses >1 year of age that had been examined twice on the same farm prior to the study. Our study may therefore be representative of horses aged >1 year but not of the entire equine population of The Netherlands.

As most research in horses is focused on individual patients rather than population-based, prevalence studies of hoof disorders in horses are rather limited. In a study conducted in the US on the frequencies of equine health problems, the 10 most frequently observed groups of health problems (from most to least frequent) were: leg lameness; dermatological problems; respiratory problems; hoof and foot disorders; reproductive problems; systemic problems; colic; whole body lameness; neurological problems; and gastrointestinal problems (other than colic; Kaneene et al., 1997). In a survival analysis of risk factors associated with the occurrence of lameness in a Michigan horse population, stallions and geldings showed an increased risk of lameness compared with mares (Ross et al., 1998). This difference between the sexes was not evident in our study and is probably related to factors such as sex-dependent differences in the intensity of use of horses (e.g. pregnant mares are used less intensively). In a representative study of equine management practices in Canada using horse-level data, it was concluded that horses may benefit from the education of their owners in all aspects of equine care (Christie et al., 2004). In another Canadian study, the associations between management, welfare and hoof disorders in a large group of 312 non-racing horses were assessed: the main hoof disorders were hoof wall breaks (32.0%) and white line disease (8.5%; Christie et al., 2006). The NAHMS report also presented data on hoof disorders, but neither a differentiation between leg and/or hoof disorders was made nor was the prevalence on specific hoof disorders presented (NAHMS, 2005).

Given the limited number of studies on hoof disorders in horses, we also compared the results of our study with findings in other species in which the horn structure is more or less comparable. The prevalence of hoof disorders in horses is in line with that of claw disorders in dairy cattle (>2 years old) at the time of regular claw trimming. In Dutch studies, 55–82% of cows had at least one claw disorder at trimming and a prevalence of 71.8% was reported in a Norwegian study (Somers et al., 2003; Sogstad et al., 2005). That prevalence of claw disorders appeared to be influenced by, among other factors, the type of flooring, parity and pasturing (Somers et al., 2003; Holzhauer et al., 2012). Based on these bovine studies it is established that, although most lesions are subclinical, they may be the starting point of more serious lesions (Lischer and Ossent, 2001). The presence of lesions such as frog cancer and keratoma in our study was low (1.1% and 1.8%, respectively) and therefore may have been based on individual predisposition rather than environmental or management factors.

To examine the influence of environmental factors on the presence of hoof lesions was also one of the aims of this study. A recent prevalence study conducted in the Middle East estimated the prevalence of thrush at 12.5% (Shokri and Khosravi, 2016) but the environmental factors present in this region are probably not comparable to those of Western Europe. In addition, our study showed that white line widening had a significantly higher prevalence in Friesian horses and in Welsh and Shetland ponies and more than in (KWPN) Warmbloods, which may evidence of a genetic component (Table 2). Perforating hoof wall cracks were significantly more prevalent when hooves were not picked out (OR = 2.8). Failure to pick out hooves can have negative consequences, because the presence of dirt leads to weakening and infection of the horn (Bell et al., 2009). The influence of the chosen bedding material appeared to be somewhat more complicated. Thrush was significantly more prevalent on humid bedding (OR = 2.9) and significantly less prevalent on shavings (OR = 0.6) than on straw. Therefore, if thrush is the major hoof problem, owners should be advised to consider how often stables are cleaned and the use of fresh wood shavings as a bedding material. In contrast, white line disease was significantly less prevalent on 'broader/softer' straw than on 'sharper/harder' flax. Apparently, some products in combination with some circumstances are more favourable than others. In that way, the outcome of this study provides insight into the possible influences of bedding type on the occurrence of hoof disorders and thus allows owners to alter the management of their horses accordingly.

Thrush was significantly less prevalent when horses were sent out to pasture (OR = 0.6), which is in line with the protective effect of pasturing on infectious claw lesions in cattle (Holzhauer et al., 2012; Bergsten et al., 2015). Sole bruises appeared to be significantly more prevalent in white hooves than in black hooves (OR = 0.2). It is possible, however, that SB are more apparent in white horn than in dark horn. Nevertheless, it is established that cows with black hooves have fewer horn lesions than cows with white hooves (Lawrence et al., 2011). Although, cold vs. warm shoeing is a hot topic in farrier's world (https://www.chronofhorse.com/forum/forum/discussion-forums/horse-care/209667-hot-shoeing-verses-cold-shoeing?372065-Hot-shoeing-verses-cold-shoeing=) no variation in the risks of lesions was found. Therefore this study does not provide any scientific argument for the preference for cold or warm shoeing in relation to a particular hoof disorder.

Unsurprisingly, all hoof disorders appear to have a multifactorial background; most hoof disorders are related to lower levels of exercise and food intake and this makes differentiation between the causes and consequences difficult. Given that good hoof horn quality is related to good nutrition, regular attention to diet is generally recommended (Anthauer et al., 2005). A UK study showed that horn quality can be influenced by external factors such as stress and, consequently, that the presence of a disorder is associated with poor horn quality (Dyson et al., 2011). Superficial and perforating hoof wall cracks were less prevalent when shoeing was applied (OR = 0.4 and 0.5, respectively). These results are in line with a study of Pleasant et al. (2012), who found that horses with loss of the structural integrity of the hoof wall were better off being shod, but this needs further investigation.

It is necessary to clarify further the influence of genetic, nutrition and other factors on the prevalence of hoof disorders in horses. The support of electronic recording, for instance using a smartphone device during regular hoof-trimming sessions could be helpful in achieving defined goals and may assist in the accurate monitoring of hoof health, thereby reducing the number of days lost due to lameness and optimizing equine welfare.

5. Conclusions

Although most of the evaluated hoof disorders identified in this study were mild and had a relatively good prognosis compared with other causes of lameness, an unexpectedly high prevalence was observed during regular hoof trimming. The most prevalent hoof diseases were thrush, superficial hoof wall cracks, growth rings, sole bruises, white line diseases, perforating hoof wall crack and widening of the white line. Different risk factors were found to be associated with different disorders. Therefore, horse owners may need to specifically adapt their management practices to reduce the risk of a specific disorder. Furthermore continuous education and preventive measures depend on adequate diagnosis and advice given by the farrier and equine veterinarian and adherence to this advice by the owners/caregivers.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.prevetmed.2017.02.013.

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