The feral horse foot. Part B: radiographic, gross visual and histopathological parameters of foot health in 100 Australian feral horses

BA Hampson,* MA de Laat, PC Mills, DM Walsh and CC Pollitt

Background It has been proposed that the feral horse foot is a benchmark model for foot health in horses. However, the foot health of feral horses has not been formally investigated.

Objectives To investigate the foot health of Australian feral horses and determine if foot health is affected by environmental factors, such as substrate properties and distance travelled.

Methods Twenty adult feral horses from five populations (n = 100) were investigated. Populations were selected on the basis of substrate hardness and the amount of travel typical for the population. Feet were radiographed and photographed, and digital images were surveyed by two experienced assessors blinded to each other’s assessment and to the population origin. Lamellar samples from 15 feet from three populations were investigated histologically for evidence of laminitis.

Results There was a total of 377 gross foot abnormalities identified in 100 left forefeet. There were no abnormalities detected in three of the feet surveyed. Each population had a comparable prevalence of foot abnormalities, although the type and severity of abnormality varied among populations. Of the three populations surveyed by histopathology, the prevalence of chronic laminitis ranged between 40% and 93%.

Conclusions Foot health appeared to be affected by the environment inhabited by the horses. The observed chronic laminitis may be attributable to either nutritional or traumatic causes. Given the overwhelming evidence of suboptimal foot health, it may not be appropriate for the feral horse foot to be the benchmark model for equine foot health.

Keywords brumbies; feet; laminitis; pathology

Abbreviations GPS, global positioning systems; HWDPD, hoof wall–distal phalanx distance; PEL, primary epidermal lamellae; SEL, secondary epidermal lamellae

Materials and methods

Subjects Twenty mature age feral horses from each of five different environments were obtained at necropsy (n = 100) following standard, controlled feral horse culling operations unrelated to the research. The study group had a mix of the sexes (58 males, 42 females) and all subjects were at least 4 years of age, as assessed by dentition. The results of the detailed morphometric analysis of the same 100 feet, together with a detailed description of the horses and their habitats, are described elsewhere. DNA analysis of horse hair samples from four of the five populations in the current study confirmed that 93% of the genetic material was common to each population and there was no measurable difference in breed origin among the five populations.

Horse populations

The feral horse populations were selected on the basis of the substrate type, landscape topography and availability of food sources in relation to water sources in each habitat (Table 1). Substrate referred to the type of ground surface (footing) over which the horses were travelling.
Table 1. Substrate type and travel pattern of feral horse populations (n = 20) in five different locations in Australia

<table>
<thead>
<tr>
<th>Population</th>
<th>Substrate</th>
<th>Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babbiloora</td>
<td>Mixed</td>
<td>Medium</td>
</tr>
<tr>
<td>Kings</td>
<td>Hard</td>
<td>High</td>
</tr>
<tr>
<td>Musselbrook</td>
<td>Hard</td>
<td>Medium</td>
</tr>
<tr>
<td>Cliffdale</td>
<td>Sandy</td>
<td>Medium</td>
</tr>
<tr>
<td>Palparara</td>
<td>Sandy</td>
<td>High</td>
</tr>
</tbody>
</table>

“Substrate refers to the type of ground surface on which the horses travelled. Sand was considered soft and hard substrate consisted primarily of rock. Mixed substrate refers to a combination of soft- and hard-substrate types. The travel pattern of feral horses was determined by the spatial relationship between food and water in the habitat.8,9 By identifying food and available water sources in each habitat, and combining this information with global positioning systems (GPS) data derived from feral horse tracking,2 the general travel patterns of the horses in each habitat could be predicted and was defined as low (0–5 km/day), medium (5–10 km/day) or high (>10 km/day).

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Foot collection
The left forelimb of each horse was used for the radiographic and photographic assessments. Limbs were disarticulated at the radio-carpal joint, immediately packed in ice and frozen within 8 h of collection. Limbs were thawed to room temperature on the day of the laboratory study, within 2 weeks of collection.

Radiographic assessment
Feet were thoroughly cleaned in preparation for radiography. A thumbtack was inserted at the frog tip–sole junction for landmark identification. The hairline was clipped to expose the coronet. To identify the coronary band on the radiograph, a 2-mm lead-impregnated rubber strip was placed circumferentially around the distal hairline–proximal hoof wall junction and taped in place on the lateral coronet. Another 2-mm strip was taped in place from the most distal hairline on the coronet, down the midline dead centre of the hoof wall and passing under the distal wall and sole, ending at the frog tip–sole junction, to highlight the hoof wall and sole profile.

Each limb was loaded in a custom-built hydraulic loading device designed to apply a nominated downward vertical force of 1300 newtons (force exerted by 30% body weight in a 400-kg horse) to simulate a standing radiograph. The starting position for loading was with the third metacarpal bone positioned vertically and the loading arm positioned over the centre of the sagittal centre of the foot. The load was applied through the proximal carpus via a cup attached to the distal end of the hydraulic ram. To calibrate measurements, a 100-mm long stainless steel rod was placed on the ground surface in alignment with the sagittal axis of the foot. Lateromedial and dorso-palmar radiographs were obtained using a portable X-ray machine at a film-focal distance of 700 mm. Radiographs were electronically scanned to allow digital measurement and image enhancement using digital image analysing software (Image) v1.38, National Institutes of Health, Bethesda, MD, USA.

Photographic assessment
Following the radiographic assessment, feet were photographed while positioned on a custom-built photographic jig. A Nikon D100 Digital camera fitted with a 55-mm Micro Nikkor lens and Nikon SB-800DX Speedlight flash was screw-mounted to the proximal end of the jig, 700 mm from the foot. The camera was aligned to the centre of each foot and a 100-mm ruler with a hoof label was placed in the measurement plane to provide image calibration and foot identification. The feet were photographed from the dorsal, medial, lateral, solar and caudal views. Feet were then sectioned in the sagittal plane with a bandsaw and the medial portion was photographed.

Foot health assessment
The health of each foot was assessed by two operators experienced in foot health assessment (D.W. and B.H.). Digitised radiographs and digital photographs of the feet were analysed for the presence of visible abnormalities. Radiographs and photographs were coded so that the assessors were blinded to the population origin of each foot. The assessors were also blinded to each other’s assessment. Feet were assessed in random order by drawing the horse number from a container and five feet were assessed twice to determine internal validity (coefficient of variation <5%). A customised assessment protocol containing 35 points of assessment was used. Only the abnormalities detected by both assessors were recorded in the data set. Each assessor was told to assess the feet for abnormalities. An abnormality was defined as a variation from normal that, in the assessor’s experience, may affect the function of the hoof. Following completion of the foot health survey, the two assessors ranked the list of abnormalities identified as more or less significant based on the assessors’ experience of the effect of hoof abnormalities on hoof function.

Histology
Lamellar samples were collected for histological analysis from the Kings, Palparara and Babbiloora populations. Logistical problems prevented the Musselbrook and Cliffdale populations from being assessed histologically. Fifteen horses were selected at random from each population and the right forefoot was removed and processed for histology within 60 min of death. A 30-mm full thickness sagittal sample of the dorsal hoof wall that included lamellae and sublamellar dermis was taken 3 mm proximal to the distal tip of the distal phalanx and placed immediately in 10% neutral buffered formalin. Following fixation, a 5-mm² tissue block was cut from the centre of the 30-mm sample and embedded in paraffin wax. Blocks were sectioned transversely at 5 µm, mounted on Superfrost Plus slides (Menzel, Braunschweig, Germany) and stained with haematoxylin and eosin.
One author (C.C.P.), experienced in describing lamellar histopathology, used a light microscope (Olympus BX-50, Olympus Corporation Lifesciences, Tokyo, Japan) to rank each section for laminitis (nil, acute, mild chronic, moderate chronic, severe chronic).

**Ethical considerations**

The project was approved by the University of Queensland Animal Ethics Committee (AEC-PCA), monitoring compliance with the Animal Welfare Act (2001) and The Code of Practice for the care and use of animals for scientific purposes.

**Results**

**Foot health assessment**

There were 377 abnormalities identified in the left forefeet (n = 100). Each of the five feral horse populations (n = 20) had a similar prevalence of abnormal feet in the overall survey, ranging from 16% to 22%. The reported abnormalities were separated into those considered to have a minimal effect and those with a more significant effect on foot function (Table 2). A clear trend in different foot health of horses emerged in the comparison between the hard (Mussellbrook) and soft (Cliffdale) substrate habitats. Although the Mussellbrook horses had the lowest prevalence of less significant abnormalities, they also had the highest prevalence of more significant abnormalities. The situation was the reverse for the Cliffdale horses, with the highest prevalence of less significant abnormalities and the lowest prevalence of more significant abnormalities. Three feet from horses from the Kings population had no abnormalities detected.

Feet from soft substrate generally had some hoof wall flaring (Figure 1A), but the internal anatomy appeared normal (Figure 1B). Feet from hard-substrate environments appeared normal externally (Figure 2A), but showed internal derangement, including excessive HWDPD and increased coronary–distal phalanx distance (Figure 2B, C) and occasional bony abnormalities (Figure 2C).

**Histology**

Histological examination showed that the prevalence of chronic laminitis was 67%, 40% and 93% for the Kings, Palparara and Babbiloora populations, respectively (Table 3). No case of laminitis was described as acute (acute basement membrane separation, leukocyte influx) and

### Table 2. List of abnormalities* observed in a foot health survey comprising five photographic and two radiographic views of 100 left forefeet from five feral horse populations in Australia

<table>
<thead>
<tr>
<th></th>
<th>Mussellbrook (n = 20)</th>
<th>Cliffdale (n = 20)</th>
<th>Kings (n = 20)</th>
<th>Palparara (n = 20)</th>
<th>Babbiloora (n = 20)</th>
<th>Total (n = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Less pathogenic abnormalities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Capsule deviation</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>6</td>
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<tr>
<td>Medio/lateral imbalance</td>
<td>5</td>
<td>14</td>
<td>12</td>
<td>6</td>
<td>11</td>
<td>48</td>
</tr>
<tr>
<td>Hoof wall cracks</td>
<td>2</td>
<td>2</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>25</td>
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<tr>
<td>Hoof wall rings</td>
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<td>12</td>
<td>13</td>
<td>18</td>
<td>14</td>
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<tr>
<td>Medio/lateral wall flare</td>
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<td>14</td>
<td>7</td>
<td>20</td>
<td>12</td>
<td>57</td>
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<tr>
<td>Frog and bars</td>
<td>5</td>
<td>16</td>
<td>11</td>
<td>4</td>
<td>1</td>
<td>37</td>
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<tr>
<td>Narrow heels</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>8</td>
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<tr>
<td>Underrun heels</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>3</td>
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<td>Uneven heel length</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
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<td>White line defect</td>
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<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>9</td>
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<tr>
<td>Long dorsal wall</td>
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<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Dorsal wall flare</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td>74</td>
<td>59</td>
<td>64</td>
<td>53</td>
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<td>% contribution</td>
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<td>26</td>
<td>21</td>
<td>23</td>
<td>19</td>
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<tr>
<td><strong>More pathogenic abnormalities</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DP/hoof wall alignment</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>DP bony abnormality</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td>24</td>
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<tr>
<td>Excessive HWDPD</td>
<td>14</td>
<td>2</td>
<td>13</td>
<td>10</td>
<td>8</td>
<td>47</td>
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<tr>
<td>Ungual cartilage calcification</td>
<td>14</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>32</td>
<td>4</td>
<td>20</td>
<td>17</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>% contribution</td>
<td>33</td>
<td>4</td>
<td>21</td>
<td>18</td>
<td>24</td>
<td>100</td>
</tr>
</tbody>
</table>

*For the purpose of the study, an abnormality was defined as a variation from what the assessors considered as optimal and was considered to negatively affect the structure and/or function of the foot. The prevalence of abnormalities is shown for each population (n = 20), as well as the total population (n = 100). Each population shared a comparable prevalence of abnormality in the overall survey; however, the prevalence of less and more significant abnormalities, in terms of pathogenicity, varied among the populations.

HWDPD, distance between the dorsal surface of the distal phalanx (DP) and the outer hoof wall.
only one case of severe, chronic laminitis was detected. All other hoof sections were ranked as either mild or moderate chronic laminitis. Of the horses diagnosed with chronic laminitis, the most prevalent histopathological features were attenuated secondary epidermal lamellae (SEL), multibranched SEL, dystrophic tips (axial ends) of primary epidermal lamellae (PEL) and the presence of cap horn (Figure 3). It was the combination of these and other features that was used to subjectively grade the severity of laminitis.

Discussion

This observational study investigated the foot health in five populations of Australian feral horses. Of the 100 left forefeet examined, only three were considered to be free of abnormalities and these were from the same hard-substrate, high-travel population (Kings). This same population also contained a high degree of abnormality, including a 67% prevalence of histopathological chronic laminitis. Overall, the majority of the feral horse feet were assigned a low to moderate abnormality score, although there was evidence of severe abnormality in some feet.

It has previously been assumed by some authors that the feral horse foot is an ideal model on which to base equine foot care practices.1–3 The adoption of this model by some groups has shifted the focus of hoof trimming away from the traditional farriery model, with a tendency towards excessive removal of the bearing border of the distal hoof wall by natural foot advocates. A previous study of the foot health of a population of feral horses in New Zealand reported a similar high prevalence of abnormalities as in the current study, including chronic laminitis.4 Thus the practice of using the ‘natural’ foot model as the optimal morphometric model on which to base foot trimming practices may need to be reconsidered.

In the present study, the external appearance of the typical hard-substrate brumby foot, which is often used as the benchmark model, was aesthetically pleasing, with little visible pathology. However, this superficial impression was misleading, as a more thorough investigation of the internal foot structure using radiographic and lamellar histological assessment revealed significant pathology. Previous observers and proponents of the ‘natural’ foot model, apparently unaware of this internal pathology, have, regardless, made assumptions and recommendations for domestic foot care, such as promotion of solar loading and excessive bevelling of the distal hoof wall.

We selected the habitats for the current study on the basis that they contained different substrate types, which determined different travel patterns of the horses. Our previous study, which investigated the hoof morphology of the same 100 horses, found that habitat influenced 37 of the 40 morphological parameters measured.5 An earlier genetic study of four of the five feral horse populations in the current study found no significant difference in the genetic origins of the horses6 and there were no significant differences in nutritional parameters likely to be responsible for the differences in foot health.7 From our separate considerations of the effect of environmental substrate and travel patterns, we concluded that both factors influenced foot morphology. Each of the five populations had a different hoof type and each displayed foot abnormalities that were unique to their
environment. Two of the most significant abnormalities detected were secondary remodelling of the distal phalanx and increased HWDPD. Previous reports suggested that these changes are consistent with chronic laminitis and this was confirmed by histopathological examination in three of the five populations. There is evidence to support the possibility that feral horses from hard-substrate environments may suffer from foot pathology that is similar to traumatic laminitis in domestic horses. Linford induced traumatic laminitis by trimming the bearing border of the hoof wall to the level of the sole and then housing the horses on a hard surface for 4 months. The findings reported were disruption of the lamellar architecture, solar chorium haemorrhages, solar margin fractures and distal phalanx remodelling.

The necessity for some feral horses to travel long distances over hard substrate may lead to overuse or concussive injuries to the distal phalanx and lamellar suspensory apparatus of the distal phalanx. The high prevalence of calcified ungual cartilages in feet from the hard-substrate environments, particularly the Mussellbrook population (70%), supports a concussive injury aetiology. Although horses in the Kings population were able to travel long distances to food and water along soft tracks worn through the hard substrate, the Mussellbrook horses were restricted to hard, rocky substrate, unaffected by stock erosion, for most of their travel. The difference between the two areas in the mechanical properties of the substrate may account for the different prevalence of calcified ungual cartilages in the two populations. Likewise, the difference in substrate hardness may also account for the difference in the HWDPD and other signs of traumatic laminitis among the five populations. Although the hard-substrate foot type had significant internal pathology, horses in these populations appeared sound and were able to travel large distances over very challenging terrain. Feral horses living on hard substrate had significantly greater mean epidermal sole depth (12.6 ± 0.77 mm) than either the feral horses from a soft-substrate environment (9.6 ± 0.59 mm) or domestic Thoroughbred horses (10.6 ± 0.52 mm). Horses living in a hard-substrate environment also had a shorter toe length (Kings 29.1 ± 0.6 mm) than either the horses from a soft-substrate area (Cliffdale 34.6 ± 1.4 mm) or the domestic horses from previous studies (Kummer: 36 ± 0.47 mm; Linford: 31.4 ± 3.0 mm). A reduction in toe length has been shown to reduce the peak moments substantially at the onset of breakover. It may be that the robust foot structure and the unique foot morphology of these horses is protective against the mechanical trauma and pain often associated with chronic laminitis in domestic horses.

The feet from the soft-substrate, moderate-travel horses (Cliffdale) did not have abnormal radiographic features. In the present study, the
HWDPD of the Cliffdale population was significantly less ($P < 0.05$) than that of the horses from the hard-substrate environments in our previous study.5 Therewerenoradiographicsignsof laminitisintheCliffdale (soft substrate) population. Hoof wall flaring and splitting were common in feet from soft-substrate environments, but were absent in feet from hard-substrate areas. The hard substrate may have induced significant internal abnormalities, but the high rate of hoof wear may have protected against less significant foot abnormalities. The significance of this protective effect, however, is not fully understood.

A straight, short-walled hoof capsule is a feature of horses surviving in a hard-substrate environment and appears to withstand the pathological consequences of this lifestyle.

Substrate hardness may not be solely responsible for the more significant abnormalities observed in the Australian feral horses. The gross observations of laminitis in the Palpara and Babbiloo populations were confirmed by histopathology. These environments did not contain substantial areas of hard substrate compared with the Muswellbrook and Kings areas. The presence of laminitis in these populations may be explained by nutritional factors. In Palpara, a significant flood occurred 3 months prior to sample collection, generally considered to be a ‘once-in-10-years’ event, and caused a flush of previously dormant plants, including grasses, forbes, legumes and native sorghum (*Echinochloa turnerana*), which is reported by local stockmen to cause severe lameness in horses allowed to graze it. The feral horses had free access to this pasture for the duration of its

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**Figure 3.** Photomicrographs of mid-dorsal hoof wall lamellar sections (H&E) from Australian feral horses. (a) Hoof epidermal lamellae are uneven in length, with blunt, rounded tips (black arrowhead) devoid of secondary epidermal lamellae (SEL). The keratinised axis of some primary epidermal lamellae (PEL) is convoluted and compressed (white arrowhead). Lamellae adjacent to the hoof wall contain cap horn (white arrow). (b) Isolated islands of lamellar epidermis at PEL tips (black arrowhead) are dyskeratotic and resemble tubular cap horn. SEL occasionally present (black arrow). (c) The keratinised axis of the PEL is sometimes discontinuous in zones that are convoluted (black arrow). Instead of being organised into symmetrical rows of SEL, epidermal-basal cells form a contiguous mass on either side of the PEL (black arrowhead). When present, SEL are often oriented towards the hoof wall (white arrowhead), which is the reverse of the normal arrangement. (d) Some midlamellar SEL are long and narrow with pointed tips (black arrowhead) instead of the usual rounded tips. PDL, primary dermal lamellae.
survival and we hypothesise that the high prevalence of laminitis (40%) in their feet was related to carbohydrate overload from opportunistic feeding, similar to laminitis caused by grain overload.\textsuperscript{18} The prevalence of laminitis was high in the Babbiloora horses (93%), whose environment was unique among the feral horse habitats because it is situated within prime cattle grazing country that is cultivated with exotic pastures, including buffel grass (\textit{Cenchrus ciliaris}), Rhodes grass (\textit{Chloris gayana}), green panic (\textit{Panicum maximum} var. \textit{trichoglume}) and silk sorghum (\textit{Sorghum halepense} × \textit{S. roxburghii} × \textit{S. arundinacum}) species, all of which are known to contain high levels of non-structural carbohydrates and have been linked to laminitis in horses.\textsuperscript{20} A nutritional survey of feral horses in the current study found higher values than would be expected in high-quality pasture for water- and ethanol-soluble carbohydrates in all locations, but these parameters were highest in the Cliffordale population,\textsuperscript{7} which showed no radiographic signs of laminitis in the current study. Carbohydrate levels were lowest in the Babbiloora population, which had the highest prevalence of laminitis in the current study. However, the nutritional survey was performed during a sustained period of drought and thus does not relate to the sporadic events (i.e. flood) proposed to have been responsible for the nutritionally-induced laminitis in the current study. We suggest that high dietary carbohydrate levels may be tolerated by feral horses because of their high daily activity levels,\textsuperscript{8,9} but sporadic environmental events, as described, producing extremely high levels of dietary carbohydrate may not be tolerated without consequences for foot health.

The lifestyle of feral horse populations can be very challenging. In some parts of Australia they walk extremely long daily distances because of the long distances (>65 km) between food and water sources.\textsuperscript{8,9} Hampson et al. reported, from data collected by GPS, that the majority of feral horse travel is performed at a slow walking pace,\textsuperscript{9} yet significant foot abnormalities develop under this regimen. Thus, repeated low-load, concussive conditions, such as unavoidable travel over hard terrain, predispose horses to the foot abnormalities described here. The pathogenesis of the laminitis detected in some populations may be attributable to free grazing of pastures and browse that are high in non-structural carbohydrates, despite the horses being extensively free-ranging. It appears that the vulnerability of \textit{Equus caballus} to foot pathologies such as laminitis extends even to horses leading a ‘natural’ existence in ‘outback’ Australia.

\textbf{Study limitations}

A limitation of the current study is the qualitative and subjective nature of the identification and classification of hoof abnormalities. Whenever possible, we used recognised objective measures of pathology indicators, such as the HWDPD, to support a subjective assessment, but this was not possible with the majority of abnormalities identified. This assessment was performed in the same manner that a practising veterinarian or experienced farrier would approach a clinical case and the same assumptions were made concerning the effect that the abnormalities may have on hoof function. Clearly, there is a lack of objective evidence to validate the pseudoclinical assessment performed in this study. However, the combination of photographic and radiographic images with lamellary histological examination enabled the assessors to obtain a more informed view of foot health than is available to many clinicians. Because of the logistical challenges of obtaining detailed data in remote areas, the left and right forelimbs were used in combination to describe foot health. The assumption was then made that the feet presented symmetry. Although left/right asymmetries are frequently encountered because of the athletic pursuits of domestic horses, we have found symmetry in feral horse feet, as described previously.\textsuperscript{7}

Our observations were limited to gross external, internal and radiographic assessments of foot health within five feral horse populations and histopathological confirmation of chronic laminitis in three. Logistical difficulties prevented collection of lamellar samples for histology in two of the populations. It was not known if subject horses experienced clinically detectable lameness, stress fractures, ligament or other soft tissue injuries. The population samples were potentially biased because they were limited to horses that were still alive after surviving the extremes of several Australian environments. Many horses experiencing similar or more profound pathologies to those observed in this study may have died as a consequence of failure to cope and thus were not included in the sample. Finally, environmental conditions were severe during the sample collection period, with some populations experiencing severe drought stress and bushfires while others had recently experienced unseasonal rain and flooding, with the associated abundance of carbohydrate-rich food.

\textbf{Conclusion}

Horse owners face the challenge of creating a housing environment that is most conducive to their horse’s health. This may include the provision of a surface under foot that balances hoof growth and wear and promotes musculoskeletal preparedness for the environment in which the horse will be used. There is a choice of substrates for housing horses and there are active feeding systems that can modify the daily distance travelled by horses.\textsuperscript{21} The present study identified the negative long-term implications of substrate and travel pattern on foot health. Although feral horses living and travelling on hard substrate appear to have robust feet, modified by the environment and able to withstand locomotion over hard substrates, the current study suggests that there are some negative consequences associated with this lifestyle.

The results of this analysis of the foot health of feral horses contain a warning of the risks and consequences for domestic horses engaged in extreme pursuits, such as endurance racing, and police patrol work on hard concussive footing such as paved roads. Recommendations can be drawn from this study regarding the design of equine housing, particularly with respect to the hardness of footing on which horses are kept and the access to pastures that are high in non-structural carbohydrates.

These data could be used by the equine husbandry community to make informed decisions on the value of using the feral horse foot to guide domestic horse foot care practices. The study of foot health in extreme environments may also provide data that enables a better understanding of the risks to domestic horse foot health associated with equine sporting and occupational pursuits, such as endurance riding and sustained activity over hard footings. Furthermore, the effect of the free consumption of native and exotic pasture and browse
(trees and shrub) species on the foot health of the feral horses described here may provide insight into dietary-related foot disease in domestic horses.

This work highlights the importance of using empirical methodology, a large sample size, thorough investigation and independent, blinded observations to obtain data for use in the guidance of hoof care practice. Further investigation of the feet of horses is warranted to determine the existence of pathology before the consequences of the environment in which they live and work can be fully established, and to fully understand the effect of various footings on the health and wellbeing of domestic horses in managed care. Currently, there is no clear evidence to suggest that the feral horse foot is preferable to the model of foot care currently accepted and used by mainstream veterinarians and farriers. However, it is possible that the hard-substrate foot type, because of its robust nature and biomechanical function, allows the feral horse to withstand significant foot pathology without showing overt lameness, thus assisting the horse to survive in extreme environments. The modern horse may have been physiologically and structurally adapted for superior speed and agility. Human intervention in breeding programs in pursuit of specific sporting and performance goals may have pushed the species towards vulnerability in some tissues, such as the lamellar suspensory apparatus of the distal phalanx. However, the feral cousins of the modern domestic horse are also vulnerable to foot pathology, despite being free from the confines and influence of human intervention.

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References

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