Overfeeding for optimal studbook showing: a comparison of subjective and objective techniques to monitor the effect of condition on the status of the locomotor apparatus in Shetland ponies.

Melanie Klompenmaker

University Utrecht

18-8-2018

ABSTRACT

Background and aims:

Traditionally, Shetland ponies are overfed for optimal studbook showing, simultaneously increasing their laminitis risk. Thus, this study aimed to prove that obese ponies being on a double diet would be suffering from a subclinical lameness of both front feet. The administration of hoof percussion would increase and that of a local block would decrease the sensitivity of the hooves, illustrated from both subjectively scored and objectively measured parameters.

Materials and methods:

A group of n=10 adult Shetland mares (Mean±SD 5.0±2.1 years; 102.8±3.8 cm) had been randomly (n=5) assigned to two different diets for 8 months resulting in a normal (100% ratio: 189±15 kg), and an obese (200% ratio: 247±42 kg) group. A n=18 infrared (IR) camera Optical Motion Capture (OMC) system (Qhorse®; 200Hz) and n=3 reflective markers at Head, Withers, and Pelvis were used to objectively assess their kinematics before and after a diagnostic nerve block of their forefeet at similar speeds (before: 2.71 m/s, after: 2.67 m/s).

Results:

In the obese group diverging hoof rings and dorsal hoof wall percussion scores were clearly higher. The heartrates in the control group did increase after locomotion measurements (before: 29,8 hb/m, after 40,9 hb/min), while the heartrate in the obese group stayed the same (before 47,2 hb/min, after: 50,3 hb/min). After blocking the Stride Duration (before: 0.51s, after: 0.55s) in the obese group significantly increased ($P<0.05$), in contrast to the normal group (before: 0.52s, after: 0.52s). The stride frequency decreased in the obese group after blocking (before: 1,94 strides/s, after 1,85 strides/s) while the average speed stayed the same (before 2,65 (m/s), after 2,60 (m/s).

Conclusions and clinical relevance:

Using objective gait analysis equipment, we found locomotor parameters for monitoring subclinical foot pain. Apparently, but not surprisingly, traditional doubled feeding has put the obese group at risk for painful feet; their extra positive blocking response possibly illustrates that these obese animals -when pain free- would more optimally perform at studbook showing because of a higher stride duration and decrease of stride frequency compared to control ponies.

INTRODUCTION

Laminitis is a common disease in the equine population. The inflammation of the laminae causes severe pain and is responsible for the typical stance in acute laminitic ponies. In the course of the disease, the distal phalanx may fail to maintain its attachment to the lamellae of the inner hoof wall. Due to the simultaneous tension of the deep digital flexor tendon on the palmar side of the coffin bone, this may result in rotation or sinking of the coffin bone (Hood 1999). These pathological changes may lead to long term devastating loss of function. To prevent the development of these pathological changes in the hoof, the diagnosis of acute laminitic patients must be confirmed promptly to consider the medical and orthopaedic treatment options as well as address the underlying cause of the laminitis in the individual patient. To achieve an effective treatment protocol, the collaboration between equine vets and farriers is crucial, but starts with an accurate diagnostic lameness exam.

There are different risk factors that can contribute to the development of laminitis, for example toxins, metabolic conditions (including EMS), and a mechanical overload.

Ad 1: Concerning toxins, after an overload of carbohydrates, more fermentation into lactic acid and thus Streptococcus bacteria start to proliferate in the hindgut. Thus, the pH in the gut decreases and this will lead to lysis of a different set of gut bacteria. Toxic components of the cell wall of these bacteria will be released (Valentinis, Morrione et al. 1999). Presumably, the endotoxins will activate platelets that in their turn will activate leukocytes (Valentinis, Morrione et al. 1999). In case of laminitis induced by an overload of carbohydrates, an increase in leukocytes can be found in the laminae. This can be found before the degeneration of the basement membrane is visible. So, it is thought that the leukocyte infiltration is the cause of the structural changes in the laminae and that it is not a secondary reaction (Moore, Eades et al. 2004). Furthermore, an increase in macrophages and monocytes can contribute to these changes (Moore, Eades et al. 2004). An overload of carbohydrates can also lead to vasoconstriction in the hoof, which will increase the risk of developing laminitis (Saegusa, Yamaji et al. 2009).

Ad 2: Horses which are obese, will become hyper insulinemic. High levels of insulin can stimulate vasoconstriction in the hoof even more (Beattie, McIntosh et al. 2010). So, obese ponies, which have received a relative overload of carbohydrates, would have a greater chance of developing laminitis than non-obese ponies.

Ad 3: Last but not least, obese ponies have an increased (fore vs hind) hoof loading and would have even a greater chance of developing laminitis than non-obese ponies.

Overfeeding ponies is used for studbook showing because of the prejudice that obese ponies would show better gaits compared to normally fed ponies. The aim of this study was to prove that obese ponies being on a double diet would be suffering from a subclinical lameness of both front feet. The administration of hoof percussion would increase and that of a local block would decrease the sensitivity of the hooves, illustrated from both subjectively scored and objectively measured parameters.

MATERIALS AND METHODS

PONIES

The data were collected from a total group of n=10 adult Shetland ponies (see Appendix 8). They were owned by the Department of Equine Sciences of Utrecht University and were part of a larger research project into the epigenetic effects of Equine Metabolic Syndrome in horse embryos. All ponies were mares of different ages (Mean ±SD 5.0±2.1 years). The total group of ponies was randomized into two groups (normal vs obese), with both groups n=5.

HOUSING

The ponies were kept in the stables of the Faculty of Veterinary Medicine in Utrecht, the Netherlands (Figure 1). The ponies were stabled separately in separate boxes (2 × 2 m) and bedded on wood shavings. Every day they went in groups into the paddock for the same amount of hours.

Figure 1. Photographical illustration of the individual housing conditions of the ponies.

CONDITION

The ponies were fed individually. The diet was started at May 2014 and consisted of concentrate (Pavo®) and hay (Kerbert, et al. 2016). The control ponies were fed on a diet of 85% hay and 15% concentrates covering 100% DE (digestible energy) for maintenance and will be referred to as the 'normal group'. The obese ponies were on a diet of 45% hay and 55% concentrates covering 200% DE for maintenance and will be referred to as the 'obese group'. The diet of the ponies in the obese group was build up in a few weeks, as described by (Carter, Geor et al. 2009), to a 200% maintenance DE diet. The hay was weighted for every pony individually by use of a Berkel® scale and the concentrate was weighted for every pony individually by use of a Joy® digital scale. Glucose Tolerance Tests (OGTTs) were done once a month to determine insulin resistance.

BODY WEIGHT

All ponies have been weighted from the first day of the locomotion measurements. The body weight is shown in Table 1 and Figure 2. There is a clear difference between the control group (189±15 kg) and the obese group (247±42 kg) which is developed in a period of 8 months by feeding two different diets; resulting in a control group (which was fed a 100% DE ratio), and an obese group (200% DE ratio). In Appendix 1 the individual body weights and heights can be found, and in Appendix 2 the photographical illustrations.

	Mean (kg)	SD
Control	189,2	15,1
Obese	246,8	42,4

Table 1. Tabular overview of the body weight (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

In Figure 2 the trend of higher weights in the obese group compared to the lower weights in the control group is visualised. A clear difference between the two groups can be seen.

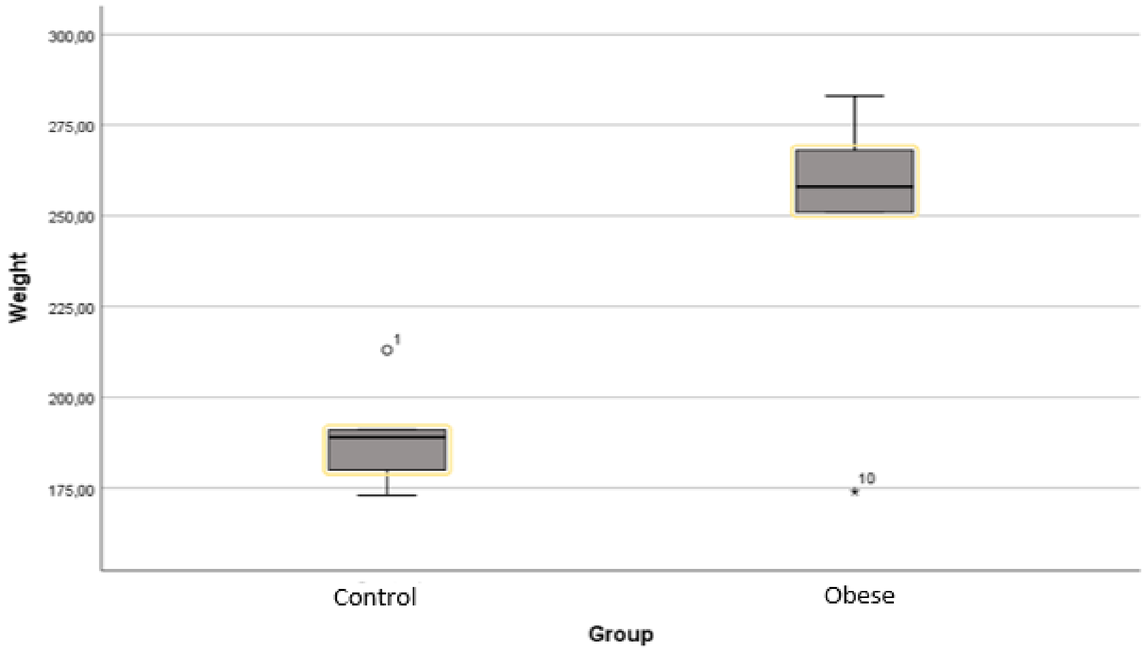


Figure 2. Graphical illustration of the bodyweight for the total group of n=10 ponies, comparing the Control to the Obese group.

HEIGHT AT WITHERS

The height of the ponies is shown in Table 2. There is a slight difference between the control group and the obese group (102.8±3.8 cm).

	Mean (cm)	SD
Control	101,5	3,3
Obese	103,0	4,5

Table 2.Tabular overview of the height (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

PAINSCORE HEARTRATE

Before the locomotion measurements started the heartrate in rest was measured while the ponies were in the stables (T=0). These measurements were performed in duplicate, following the protocol (Appendix 3). One hour after the locomotion measurements the heartrates were measured again (T=1).

PAINSCORE HOOFPERCUSSION

The hoof percussion was done by one and the same experienced veterinarian. The percussion started with the left front foot, followed, after a walk over the brick lane in trot, with percussion of the right front foot.

Figure 3. Percussion of the left front foot in a control pony.

Figure 4. Percussion of the right front foot in an obese pony.

After the first two times of percussion the ponies were administered an anaesthesia of the palmar digital medialis and lateralis nerve with 1.5 ml Mepivacaine® (referred later as nerve block). Percussion for the second time started 15 minutes after administration of the nerve block (Appendix 5).

Figure 5. Subcutaneous injection for an abaxial, mepivacaine block.

Figure 6. A detailed overview of the exact distal limb location.

The veterinarian who performed the hoof percussion also gave a score between 1 – 5 for the pain reaction/soreness caused by the percussion.

NSPS VETERINARIAN SCORE

Two veterinarians of the Dutch Shetland Pony Studbook (NSPS) scored the gait quality of the ponies and evaluated the quality and shape of the hooves (Appendix 6).

Figure 7. The two NSPS veterinarians discuss the judged scores.

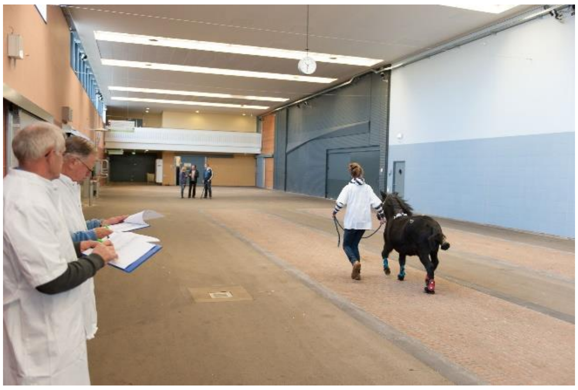


Figure 8. Simultaneous Qhorse measurements at the trot.

UKP FARRIER SCORE

The farrier who works at the Department of Equine Sciences scored the quality and shape of the hooves from the ponies (Appendix 7).

X RAY ANALYSIS

From both front feet X – rays were taken for measuring the conformation of the coffin bone. Ponies with EMS have an increased risk of laminitis and thus an increased risk for a subsidence or tilt of the coffin bone (Baxter 1994). The x – rays were taken from a lateromedial position (Hunt, Wharton 2010, Collins, Dyson et al. 2012). The distance from the coffin bone to the proximal dorsal hoof wall and distal dorsal hoof wall and the thickness of the sole is measured by using the program Impax (Cripps, Eustace 1999a) using the methods visualised in Figure 9.

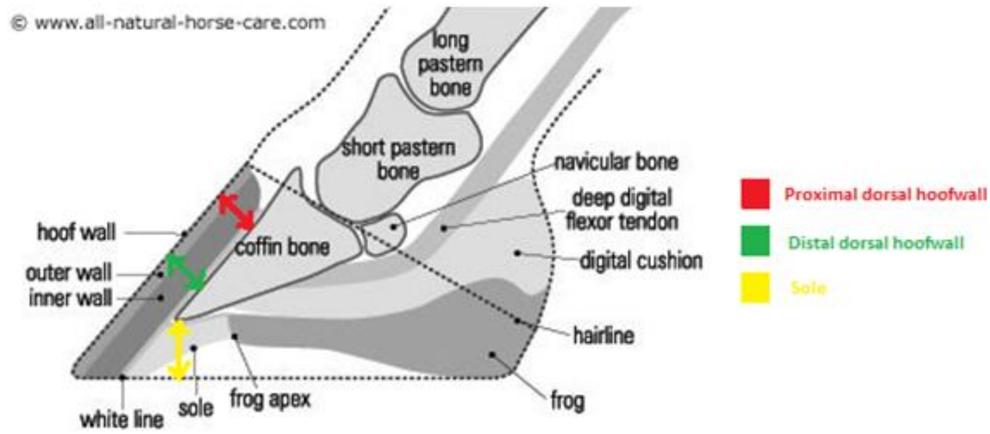


Figure 9. Schematic cross-sectional overview of hoof anatomy (www.all-natural-horse-care.com).

OBJECTIVE DATA COLLECTION

A n=18 infrared (IR) camera Optical Motion Capture (OMC) system (Qhorse®; 200Hz) and n=3 reflective markers at Head, Withers, and Pelvis was used to measure possible lameness, presumably located in the front feet in the obese group. There are 5 points of measurement; measurement 1 is a neutral measurement at the start when the ponies have achieved their steady state. Measurement 2 and 3 is respectively after hoof percussion of the left front foot and the right front foot. Measurement 4 and 5 are the same as 2 and 3, but 15 minutes after the nerve block. Before each measurement, the ponies did have a warm-up period of 5 minutes (Oosterlinck, Hardeman et al. 2013). Subsequently, the ponies were walked over a brick lane by one and the same experienced handler, in trot. A run will be valid if a complete locomotor pattern is recorded consecutively and if the velocity was in a present range of 1.7 - 2.7 m/s at trot. In addition, the ponies had to look straight forward and had to maintain a constant gait. Therefore, the kinematic parameters velocity, stride duration, stride frequency were analysed.

STATISTICS

SPSS (version 25, IBM corp©) was used for an initial statistical, student exploration of the kinematic data (Linear Mixed Model Analysis with 'Body condition' and 'Block' as fixed parameters; $P<0.05$). Additional tests for normality, and a further (linear / nominal) in depth statistical processing of the subjectively scored clinical and the objectively measured kinematic data before and after anaesthetic blocking and percussion will be performed, thereby also relying on custom-made Matlab scripts (Matlab R2015a).

RESULTS

SUBJECTIVELY SCORED DATA

HEARTRATES

The heartrates of the control and obese group are shown in Table 3 (the individual heartrates can be found in Appendix 4). The heartrate was measured before locomotion measurements were performed (T=0) and an hour after the locomotion measurements (T=1) at which diagnostic blocking of the front feet was performed.

There is a difference in heartrates between the control and obese group at T=0. When comparing the means of the heartrates of the control and obese group there is a clear increase in the control group (11.1 heartbeats per minute) after locomotion measurements. In contrast, the ponies in the obese group did not show a clear increase in heartrate (3.1 heartbeats per minute).

	Mean T=0 (hb/min)	SD (T=0)	Mean T=1 (hb/min)	SD (T=1)
Control	29,8	1,9	40,9	7,4
Obese	47,2	2.5	50,3	1,6

Table 3. Tabular overview of the heartrates (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

In Figure 10 the trend of higher heartrates in the obese group compared to the lower heartrates in the control group is visualised.

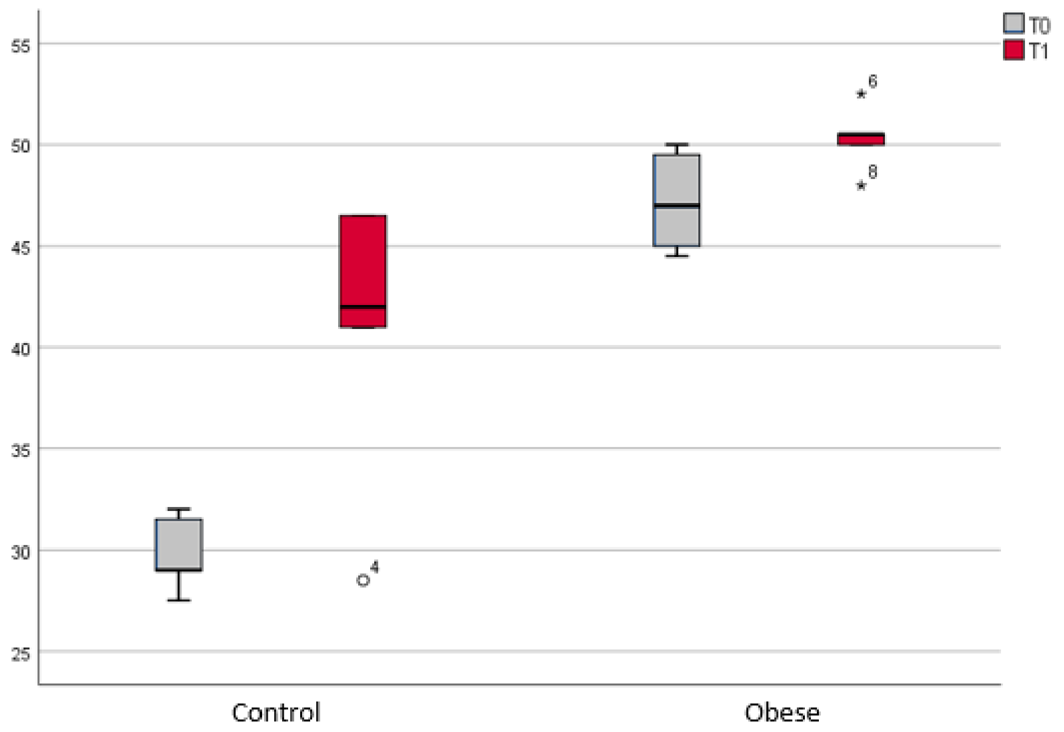


Figure 10. Graphical illustration of the heartrates for the total group of n=10 ponies, comparing the control to the obese group.

HOOFPERCUSSION

The amount of pain expressed at hoof percussion is shown in Table 4 and Figure 11 (individual reactions at percussion can be found in Appendix 5). The table shows the reaction at hoof percussion before and after administration of the nerve block. Percussion took place on both front feet separately and the expression of pain was scored on a scale from one to five. Table 4 and Figure 11 show there is a clear difference in pain expression at percussion between the obese and control group before administration of the nerve block. After anaesthesia of the front feet the reaction at percussion of the control group is comparable with the reaction before. The results of the obese groups show there is a decrease in pain reaction after the nerve block at percussion with an average decrease of 0,4 in the left foot and 1,0 in the right foot.

	Before				After			
	Left		Right		Left		Right	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control	0	0	0	0	0	0	0	0
Obese	2	1,41	2,2	1,79	1,6	1,67	1,2	1,64

Table 4. Tabular overview of the soreness at percussion (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

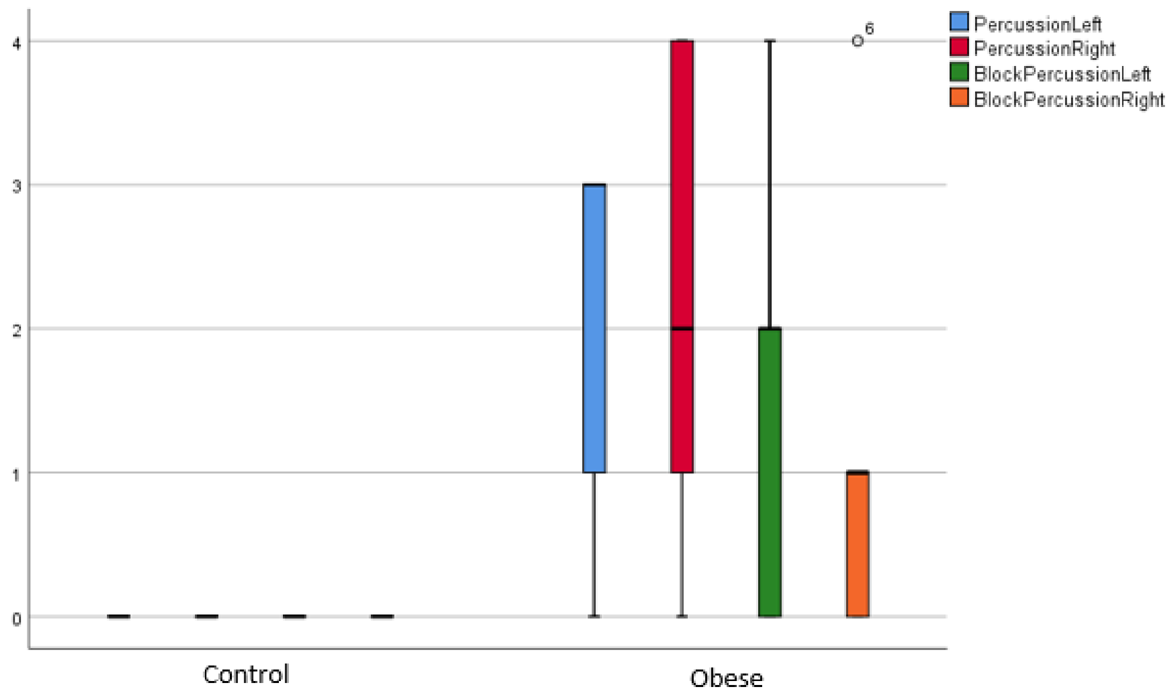


Figure 11. Graphical illustration of the expression of pain at hoof percussion for the total group of n=10 ponies, comparing the control to the obese group.

MEASUREMENTS NSPS VETERINARIANS

The rapports from the Dutch Shetland Pony Studbook (NSPS) veterinarians show (Appendix 6) multiple scores for multiple categories. The hoof quality and appearance of growth rings on the hooves do have a correlation with the presence of laminitis (Dyson, Tranquille et al. 2011). Therefore, the NSPS veterinarians were asked to score the quality of the hooves depending on the appearance of growth rings. The scale of the scores was 1 to 10 (the higher the score, the more and severe growth rings are visible on the hooves). The means and standard deviations of both groups have been displayed in Table 5 and Figure 12. In the results it is clear that the feet of the ponies in the obese group showed more signs of laminitis according to the studbook veterinarians.

	Mean	SD
Control	1,4	0,89
Obese	5,6	1,67

Table 5. Tabular overview of the hoof quality (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

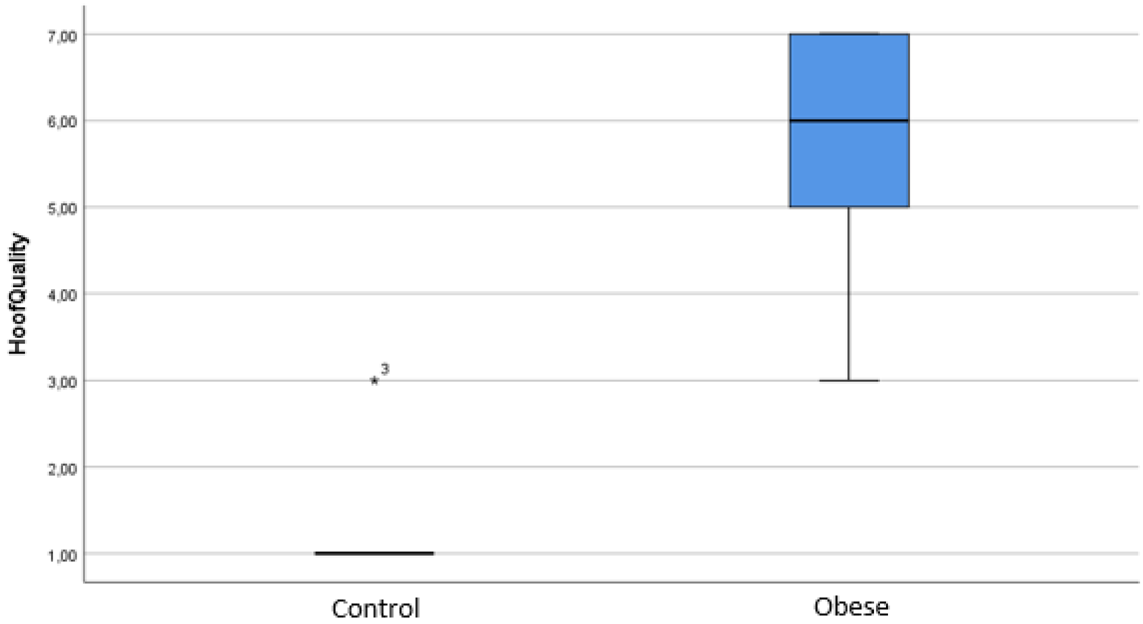


Figure 12. Graphical illustration of the Hoof quality for the total group of n=10 ponies, comparing the control to the obese group.

UKP FARRIER SCORE

The farrier who works at the Department of Equine Sciences scored the quality and shape of the hooves from the ponies (Appendix 7).

X – RAYS

All X-rays from al ponies can be found in Appendix 2. The X-rays were taken to measure if there was a subsidence or rotation of the coffin bone. In Appendix 8 there is a calculation of the difference in the distance between the distal hoof wall and the coffin bone and the proximal hoof wall and the coffin bone (Figure 9). A positive number means there is a rotation of the coffin bone, caused by the distal phalanx which failed to maintain its attachment to the lamellae of the inner hoof wall and simultaneous tension of the deep digital flexor tendon on the palmar side of the coffin bone, which is a sign of laminitis (Cripps 1999). The calculation of the rotation of the coffin bone had been used to calculate the mean and standard deviation for the control and the obese group. Table 6 and Figure 13 show that the ponies in the obese group suffered from more rotation of the coffin bone compared to the control ponies.

	Left foot		Right foot	
	Mean (mm)	SD	Mean (mm)	SD
Control	-0,44	0,23	-0,44	0,65
Obese	1,44	1,88	1,7	1,86

Table 6. Tabular overview of the rotation of the coffin bone on X-rays (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

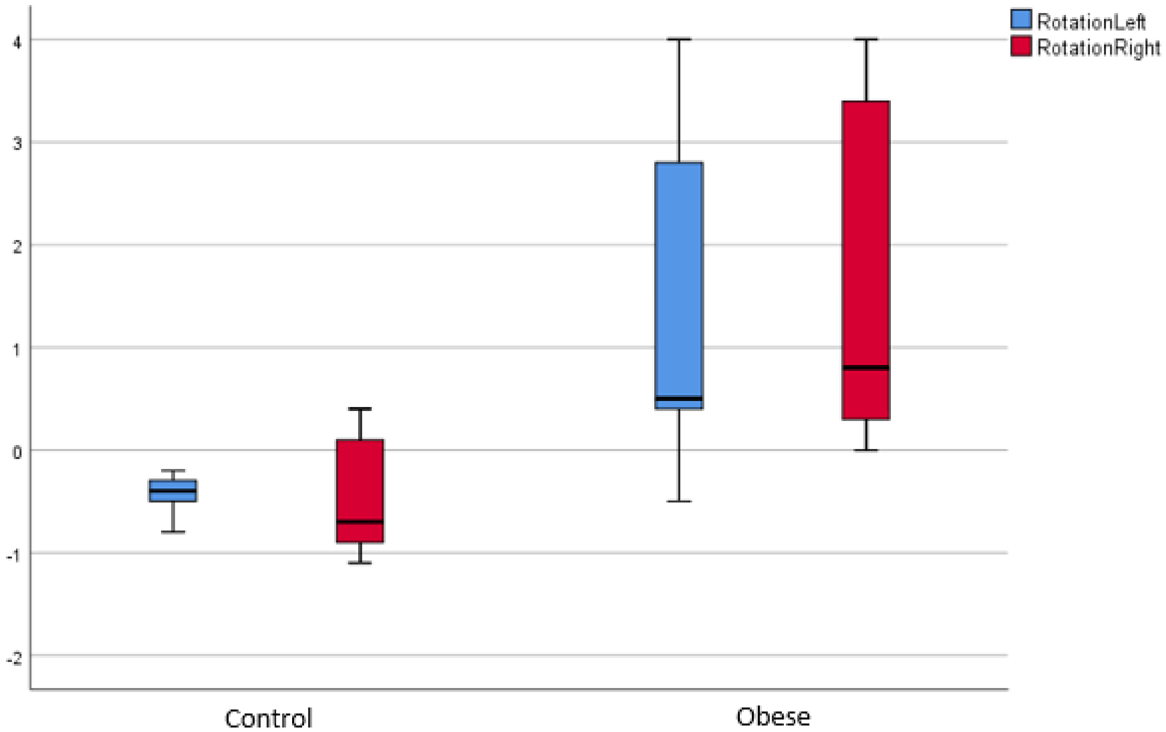


Figure 13. Graphical illustration of the rotation of the coffin bone on X-rays for the total group of n=10 ponies, comparing the control to the obese group.

OBJECTIVELY RECORDED DATA

The data of the objective measurements of the kinematic measurement system (Qhorse®) were analysed.

VELOCITY

The mean and standard deviation of the speed of the control and obese ponies are displayed in Table 7 and Figure 14. The velocity of the control ponies was slightly and significantly higher than that of the obese ponies (P<0.05), but after blocking tended to slightly but not significantly decrease in a similar way in both groups (P=0.061).

	Before		After	
	Mean (m/s)	SD	Mean (m/s)	SD
Control	2,7605	0,3362	2,7355	0,37884
Obese	2,6515	0,3526	2,6048	0,36716

Table 7. Tabular overview of the Speed average stride for the total group of n=10 ponies, comparing the control to the obese group.

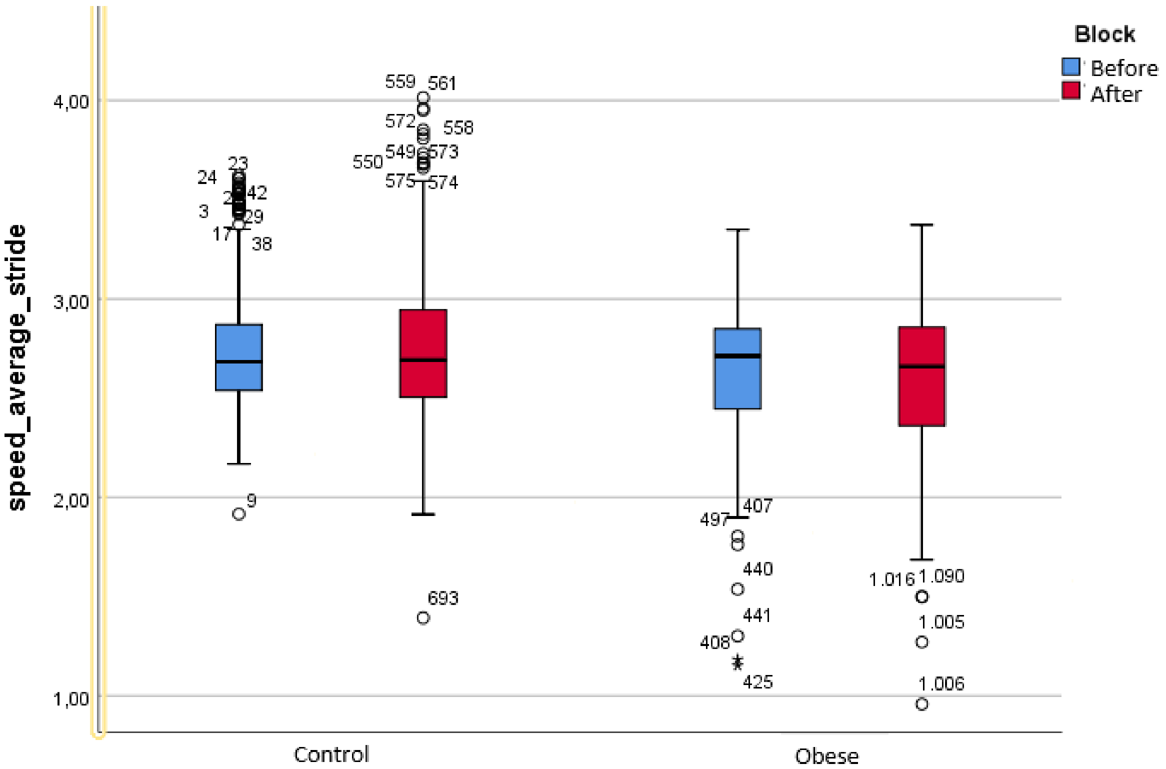


Figure 14. Graphical illustration of the velocity (speed average stride) for the total group of n=10 ponies, comparing the control to the obese group.

STRIDE DURATION

The mean and standard deviation of the stride duration of the control and obese ponies are displayed in Table 8 and Figure 15. The stride duration of the control ponies was longer compared to the obese ponies, but after nerve blocking the stride duration appeared to be significantly increased in the obese group, and significantly more in the obese ponies compared in contrast to the control ponies (P<0.05).

	Before		After	
	Mean (s)	SD	Mean (s)	SD
Control	0,5223	0,03927	0,5176	0,4506
Obese	0,5141	0,07773	0,5455	0,1303

Table 8. Tabular overview of the stride duration (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

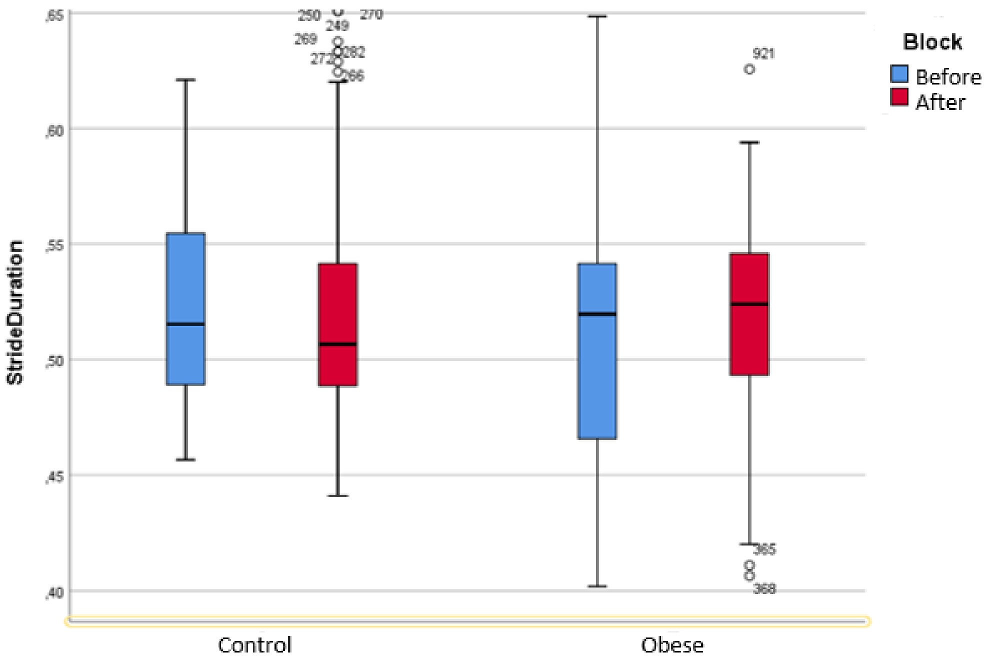


Figure 15. Graphical illustration of the stride duration for the total group of n=10 ponies, comparing the control to the obese group.

STRIDE FREQUENCY

The stride frequency (number of strides per second; Hz) can be found in Table 9 and Figure 16. The stride frequency was significantly higher in the control ponies compared to the obese ponies ($P<0.05$), but after blocking significantly decreased in the obese ponies compared to the control ponies ($P<0.05$).

	Before		After	
	Mean (strides/s)	SD	Mean (strides/s)	SD
Control	1,9841	0,3079	2,0657	0,1525
Obese	1,9420	0,4984	1,8524	0,4572

Table 9. Tabular overview of the stride frequency (Mean and SD) for the total group of n=10 ponies, comparing the control to the obese group.

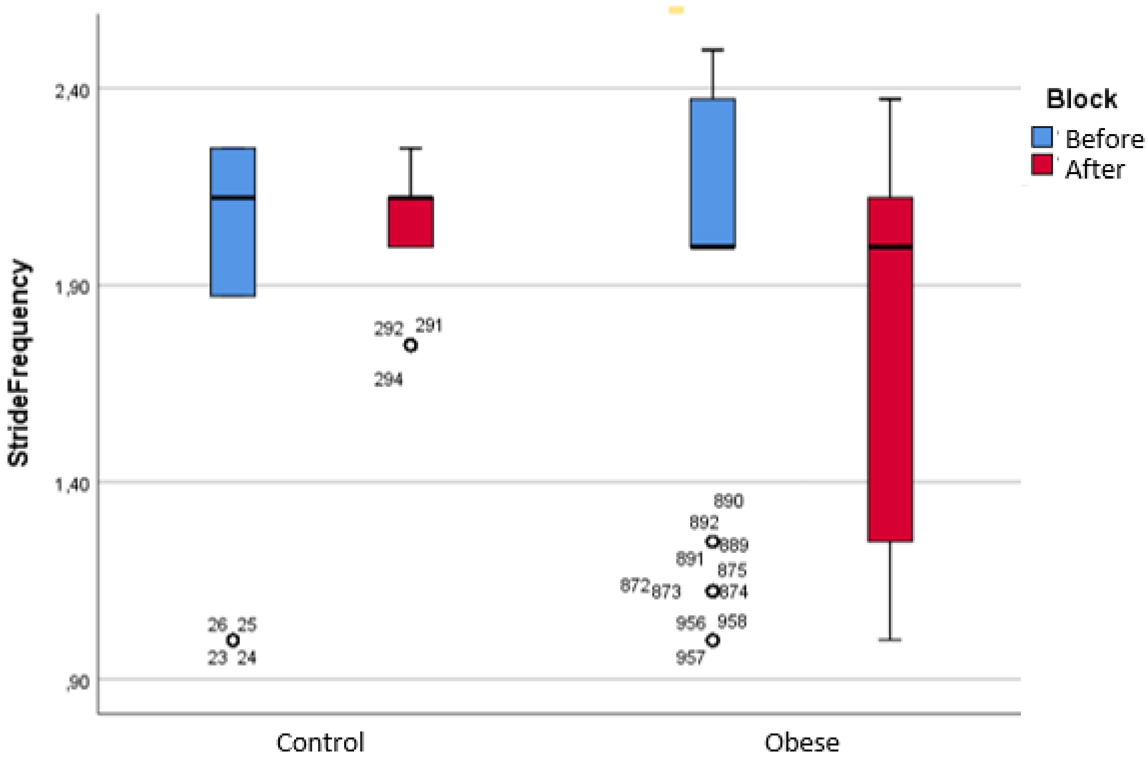


Figure 16. Graphical illustration of the stride frequency for the total group of n=10 ponies, comparing the control to the obese group.

DISCUSSION

The aim of this study was to prove that obese ponies being on a double diet would be suffering from a subclinical lameness of both front feet. The administration of hoof percussion would increase and that of a local block would decrease the sensitivity of the hooves, illustrated from both subjectively scored and objectively measured parameters. Initially, at the start of the general, long term experimental study, the ponies had been randomly selected for the control or the obese group, so their heights at the withers were randomly selected too. At the start of the present short study there was a clear, induced significant difference in weight between the control and obese group, which can be considered more reliable because of this randomization. As such, for measuring the weight of the ponies and the obese depositions, the ponies were scored using the Body Condition Score (Henneke, Potter et al. 1983).

Subjective clinical tests were performed to confirm the ponies did suffer from laminitis and thereby experienced pain in their front feet. The hoof percussion showed signs of pain in the feet (Pollitt 2010). The reaction at percussion was higher in the obese ponies compared to the control ponies. After local anaesthetic blocking the difference in clinical reaction between the obese and control group decreased, which supports the hypothesis that the obese ponies did experience more pain at percussion compared to the control ponies. Also, the NSPS veterinarians scored the hoof quality lower in the obese group compared to the control group. The score given for hoof quality depends on the appearance of growth rings on the hooves (Hunt, Wharton 2010). As the obese group did have more growth rings on their feet, this was an additional clinical sign that the obese ponies did suffer from laminitis. Despite the clear suspicion already from the clinical signs mentioned above, digital X-rays were taken to confirm the obese ponies did suffer from laminitis (Cripps, Eustace 1999b). With that, the obese ponies showed more rotation of the coffin bone compared to the control ponies (an mean rotation of 1.4 mm in the left foot and 1.7 mm in the right foot, compared to absent ‘0 mm’ rotation of the coffin bone in the control ponies) on X-rays. This proved that the obese ponies did have a subclinical laminitis and thus could possibly be showing shortened strides.

During the experiment the heartrate was also monitored as an additional pain and stress readout parameter, though an increase in heartrate can have a lot of causes. Before the kinematic measurements (T=0) the heartrate of the ponies was greatly differed between the control (Mean ± SD, 29.8 ± 1,9) and the obese groups (47,2 ± 2,5). This higher heartrate in the obese group was most likely caused by chronic pain due to chronical subclinical laminitis (Rietmann, Stauffacher et al. 2004), but also due to its chronic persistence this could be also related to the hypertension from the obesity and insulin resistance (Bailey, Habershon-Butcher et al. 2008). Nonetheless, when comparing the means of the heartrates of the control and obese group, there also appeared to be a clear acute increase in heartrate in the control group of 11.1 heartbeats per minute compared to before the kinematic measurements. That increase in heartbeats after the experimental measurements can be caused by the lack of stamina, as during the day the ponies were only paddock housed and not actively trained. In contrast, the ponies in the obese group only showed a small increase in heartrate (a mean of 3.1 heartbeats per minute), but their heart rate was already significantly elevated. That lower increase in heartrate in the obese group could also be explained from the reduced pain from the local, positive nerve block in that group (Rietmann, Stauffacher et al. 2004).

Objective, kinematic measurements did show the mean stride duration was lower in the obese ponies compared to the control ponies before local anaesthesia, which presumably at that moment was related to that pain in the feet (PEHAM, LICKA et al. 2001). After anaesthesia the stride duration of the obese ponies increased and became in fact significantly higher in contrast to the control group, which showed a more or less same stride duration after anaesthesia. This possibly illustrates that the stride duration can be longer in obese ponies, showing a higher gait quality, but only when they are not experiencing pain in their feet. As from those kinematic measurements, it also appeared that in the control group the stride frequency significantly increased after anaesthesia. That increased stride frequency in the control group can be explained by their frisky behaviour or excitement caused by administering the anaesthesia. These behavioural changes can cause horses to shorten their strides and show a more resilient gait. In the obese group, however, there was a significant decrease in stride frequency after anaesthesia. That decreased stride frequency reflects a more eased gait and an increased will to move. Other articles show similar results; horses who have to trot in more optimal circumstances, a more resilient underground made out of rubber versus a hard asphalt underground, showed an increased stride duration and a lower stride frequency at similar speeds, and thus a more eased gait (Buchner et al. 1994). To make sure the increased stride duration was not caused by a higher velocity at trot after anaesthesia (Clayton 1994) the ponies were led by the same experienced handler supposedly trotting the ponies at the same speed. Possibly due to circumstantial habituation, the average speed slightly but not significantly (P=0.061) decreased after anaesthesia in both groups, so the increased stride duration after anaesthesia in only the obese group is likely not caused by that reduced velocity expecting a reduced stride duration and frequency.

CONCLUSIONS

From this study it can be concluded that double feeding has put the obese group at risk for developing painful feet, as the obese ponies did suffer from subclinical laminitis, confirmed using several subjective clinically diagnostic and objective registration methods.

Apparently, the heartrate was significantly (chronically) higher in the obese ponies compared to the control ponies before as well as after the experiment, while the control ponies showed a small, but significant (acute) increase in heartrate after compared to before the experiment. We propose the use of the heartrate as a criterium for determining the presence of acute stress (experiment and hard surface trot), but also of chronic stress (obesity and high blood pressure).

Moreover, from the kinematic measurements it appeared that the stride duration was shorter in the obese ponies compared to the control ponies, as recorded at similar speeds. However, when the pain caused by laminitis was blocked using local anaesthesia the stride duration of the obese ponies significantly increased and became longer compared to the control ponies. In addition, after diagnostical blocking the stride frequency significantly decreased in the obese ponies, but this appears to be the result of a more eased gait and in line with the presumed absence of foot pain.

Not surprisingly, traditional double feeding has put the obese group at risk for developing painful feet as to become objectively monitored using stride duration and stride frequency as readout parameters under practical circumstances in the field and recorded at similar speeds. The extra positive blocking response possibly illustrates that the obese animals -when pain free- would more optimally perform when prepared as such for studbook showing.

REFERENCES

BAILEY, S.R., HABERSHON-BUTCHER, J.L., RANSOM, K.J., ELLIOTT, J. and MENZIES-GOW, N.J., 2008. Hypertension and insulin resistance in a mixed-breed population of ponies predisposed to laminitis. *American Journal of Veterinary Research,* **69**(1), pp. 122-129.

BAXTER, G.M., 1994. Acute laminitis. *Veterinary clinics of North America: equine practice,* **10**(3), pp. 627-642.

BEATTIE, J., MCINTOSH, L. and VAN DER WALLE, C.F., 2010. Cross-talk between the insulin-like growth factor (IGF) axis and membrane integrins to regulate cell physiology. *Journal of cellular physiology,* **224**(3), pp. 605-611.

BUCHNER, H., SAVELBERG, H., SCHAMHARDT, H., MERKENS, H. and BARNEVELD, A., 1994. Kinematics of treadmill versus overground locomotion in horses. *Veterinary Quarterly,* **16**(sup2), pp. 87-90.

CARTER, R., GEOR, R., BURTON STANIAR, W., CUBITT, T. and HARRIS, P., 2009. Apparent adiposity assessed by standardised scoring systems and morphometric measurements in horses and ponies. *The veterinary journal,* **179**(2), pp. 204-210.

CLAYTON, H.M., 1994. Comparison of the stride kinematics of the collected, working, medium and extended trot in horses. *Equine veterinary journal,* **26**(3), pp. 230-234.

COLLINS, S., DYSON, S., MURRAY, R., NEWTON, J.R., BURDEN, F. and TRAWFORD, A., 2012. Development of a quantitative multivariable radiographic method to evaluate anatomic changes associated with laminitis in the forefeet of donkeys. *American Journal of Veterinary Research,* **73**(8), pp. 1207-1218.

CRIPPS, P.J. and EUSTACE, R.A., 1999a. Radiological measurements from the feet of normal horses with relevance to laminitis. *Equine veterinary journal,* **31**(5), pp. 427-432.

CRIPPS, P. and EUSTACE, R., 1999b. Radiological measurements from the feet of normal horses with relevance to laminitis. *Equine veterinary journal,* **31**(5), pp. 427-432.

CRIPPS, P.J., 1999. Radiological measurements from the feet of normal horses with relevance to laminitis. *Equine veterinary journal,* **31**(5), pp. 427.

DYSON, S.J., TRANQUILLE, C.A., COLLINS, S.N., PARKIN, T.D.H. and MURRAY, R.C., 2011. External characteristics of the lateral aspect of the hoof differ between non-lame and lame horses. *The Veterinary Journal,* **190**(3), pp. 364-371.

HENNEKE, D.R., POTTER, G.D., KREIDER, J.L. and YEATES, B.F., 1983. Relationship between condition score, physical measurements and body fat percentage in mares. *Equine veterinary journal,* **15**(4), pp. 371-372.

HOOD, D.M., 1999. Laminitis in the horse. *Veterinary Clinics of North America: Equine Practice,* **15**(2), pp. 287-294.

HUNT, R. and WHARTON, R., 2010. Clinical presentation, diagnosis, and prognosis of chronic laminitis in North America. *The Veterinary clinics of North America.Equine practice,* **26**(1), pp. 141-153.

KERBERT, PIETERNEL M.P. SONNEVELD, DANSE C. VOSKAMP, J. DE GRAAF-ROELFSEMA, ELLEN. DE RUIJTER-VILLANI, MARTHA. BACK, W, 2016. *Does a high body condition score influence the sagittal and carpal range of motion in Shetland ponies at walk and trot?.*

MOORE, R.M., EADES, S.C. and STOKES, A.M., 2004. Evidence for vascular and enzymatic events in the pathophysiology of acute laminitis: which pathway is responsible for initiation of this process in horses? *Equine veterinary journal,* **36**(3), pp. 204-209.

OOSTERLINCK, M., HARDEMAN, L.C., VAN DER MEIJ, B R, VERAA, S., VAN DER KOLK, J H, WIJNBERG, I.D., PILLE, F. and BACK, W., 2013. Pressure plate analysis of toe-heel and medio-lateral hoof balance at the walk and trot in sound sport horses. *The veterinary journal,* **198 Suppl 1**, pp. e9-13.

PEHAM, C., LICKA, T., GIRTLER, D. and SCHEIDL, M., 2001. *The Influence of Lameness on Equine Stride Length Consistency*.*

POLLITT, C.C., 2010. Medical therapy of laminitis. *Diagnosis and Management of Lameness in the Horse-E-Book,* , pp. 371.

RIETMANN, T., STAUFFACHER, M., BERNASCONI, P., AUER, J. and WEISHAUPT, M., 2004. The association between heart rate, heart rate variability, endocrine and behavioural pain measures in horses suffering from laminitis. *Journal of Veterinary Medicine Series A,* **51**(5), pp. 218-225.

SAEGUSA, J., YAMAJI, S., IEGUCHI, K., WU, C., LAM, K., LIU, F. and TAKADA, Y., 2009. The direct binding of insulin-like growth factor-1 (IGF-1) to integrin alphavbeta3 is involved in IGF-1 signaling. *Journal of Biological Chemistry,* **284**(36), pp. 24106-24114.

VALENTINIS, B., MORRIONE, A., PERUZZI, F., PRISCO, M., REISS, K. and BASERGA, R., 1999. Anti-apoptotic signaling of the IGF-I receptor in fibroblasts following loss of matrix adhesion. *Oncogene,* **18**(10), pp. 1827-1836.

APPENDIX

1. EXTRA M&M: SIGNALMENT OF THE TOTAL GROUP OF (N=10) SHETLAND PONIES, IN A CONTROL AND A TEST, GROUP FOR WEIGHT (KG) AND HEIGHT (CM).

Number	Group (Control/Test)	Weight (kg)	Height (cm)
40	C	213	106
58	T	258	99
67	C	173	99
70	T	251	101
64	C	189	100
63	T	268	105
53	C	180	98,5
74	T	283	110
48	C	191	104
59	T	174	105

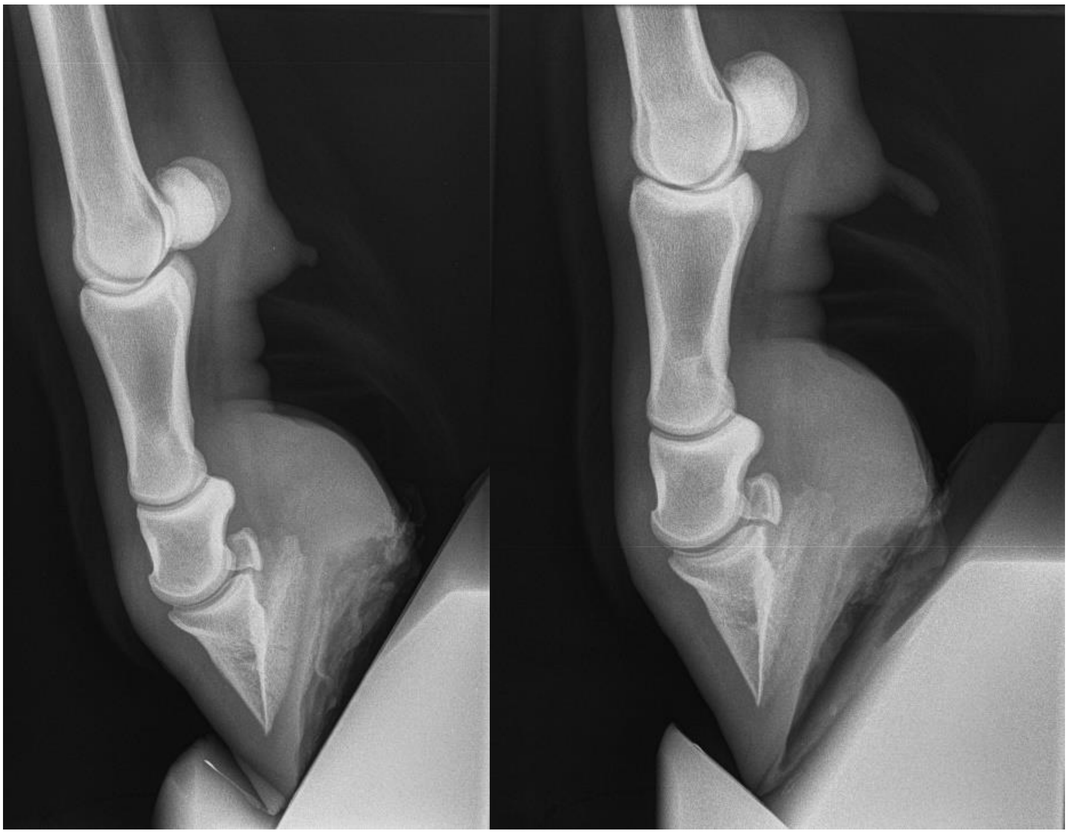
2. EXTRA M & M: PHOTOGRAPHICAL ILLUSTRATION OF THE INDIVIDUAL SHETLAND PONIES OF THE TOTAL GROUP (N=10).

Name: Geke (40)
Control/ test: control

Age: 3 Y, 6 M

Weight: 213 kg

Height: 106 cm



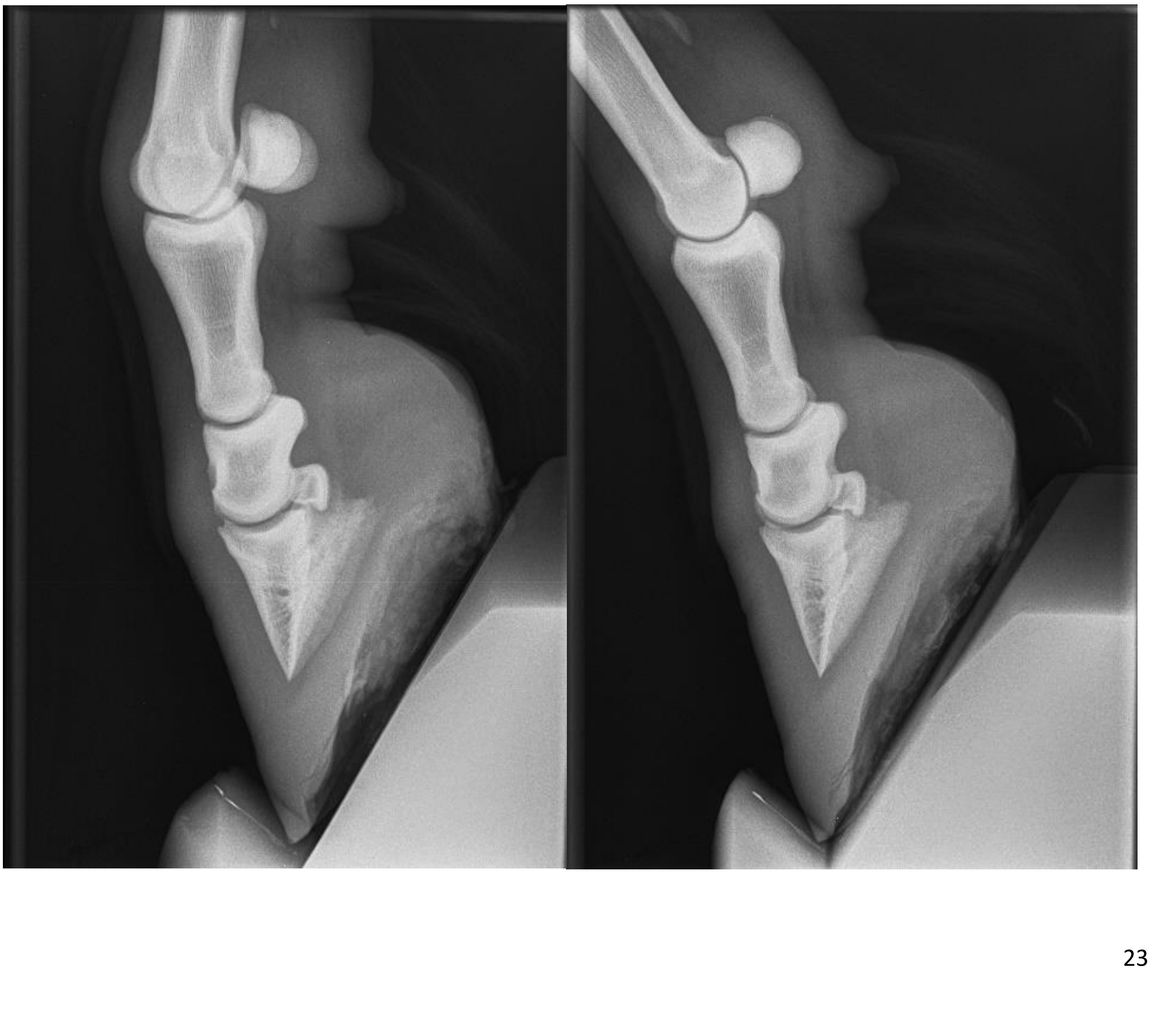
Name: Diewertje (58)
Control/ test: test

Age: 6 Y, 6 M

Weight: 258 kg

Height: 99 cm


58

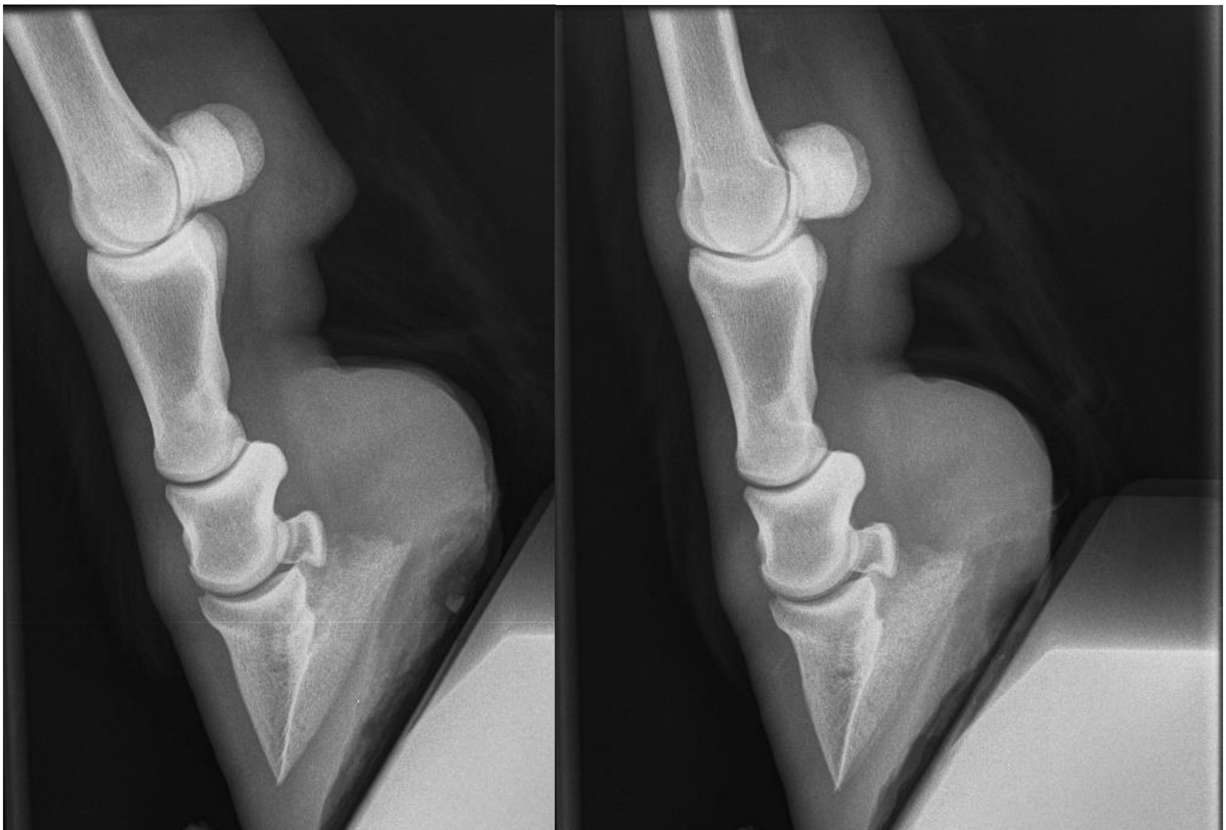


Name: Bontje (67)
Control/ test: control

Age: 8 Y, 6 M

Weight: 173 kg

Height: 99 cm

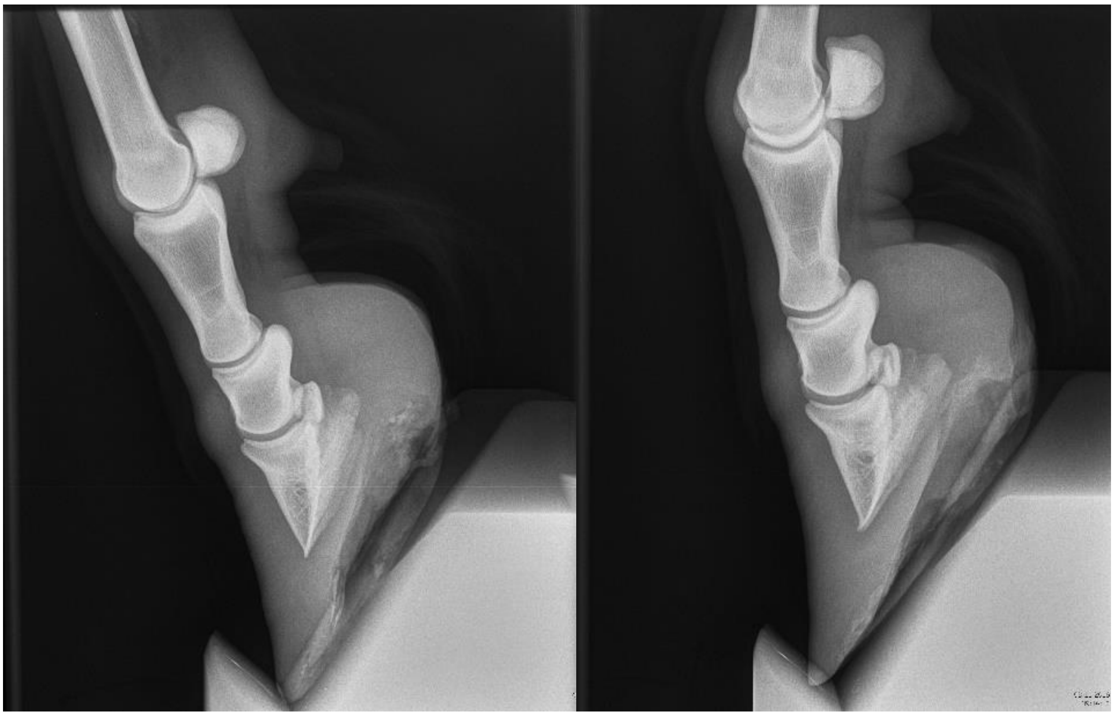


Name: Bonte Vos (70)
Control/ test: test

Age: 9 Y, 7 M

Weight: 251 kg

Height: 101 cm

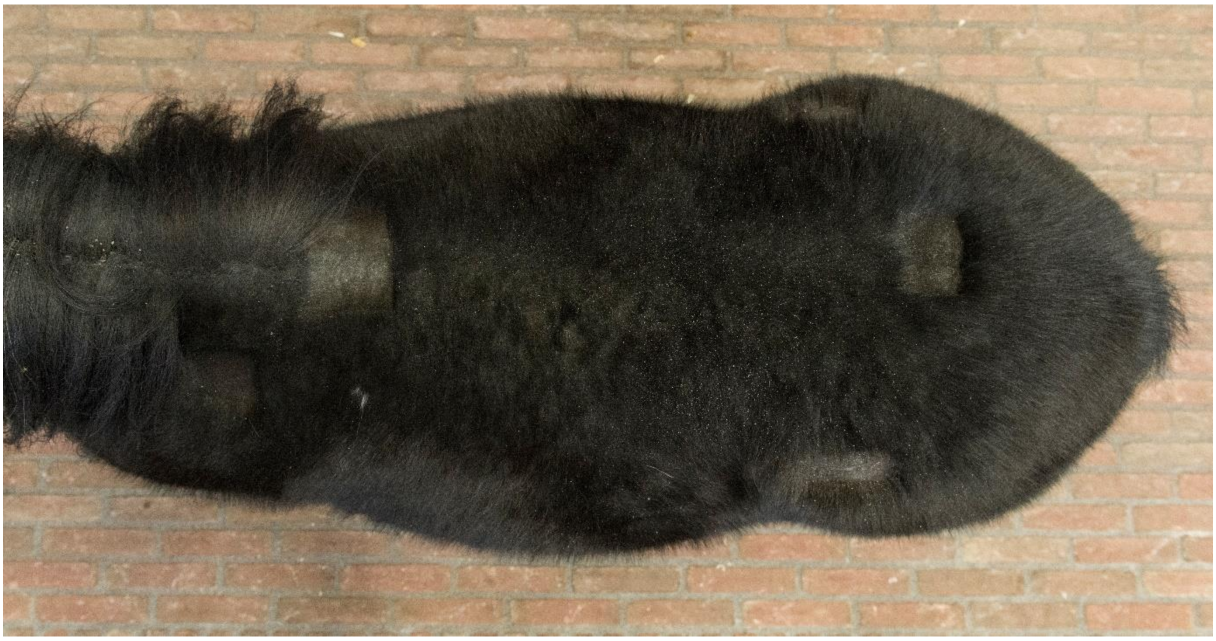


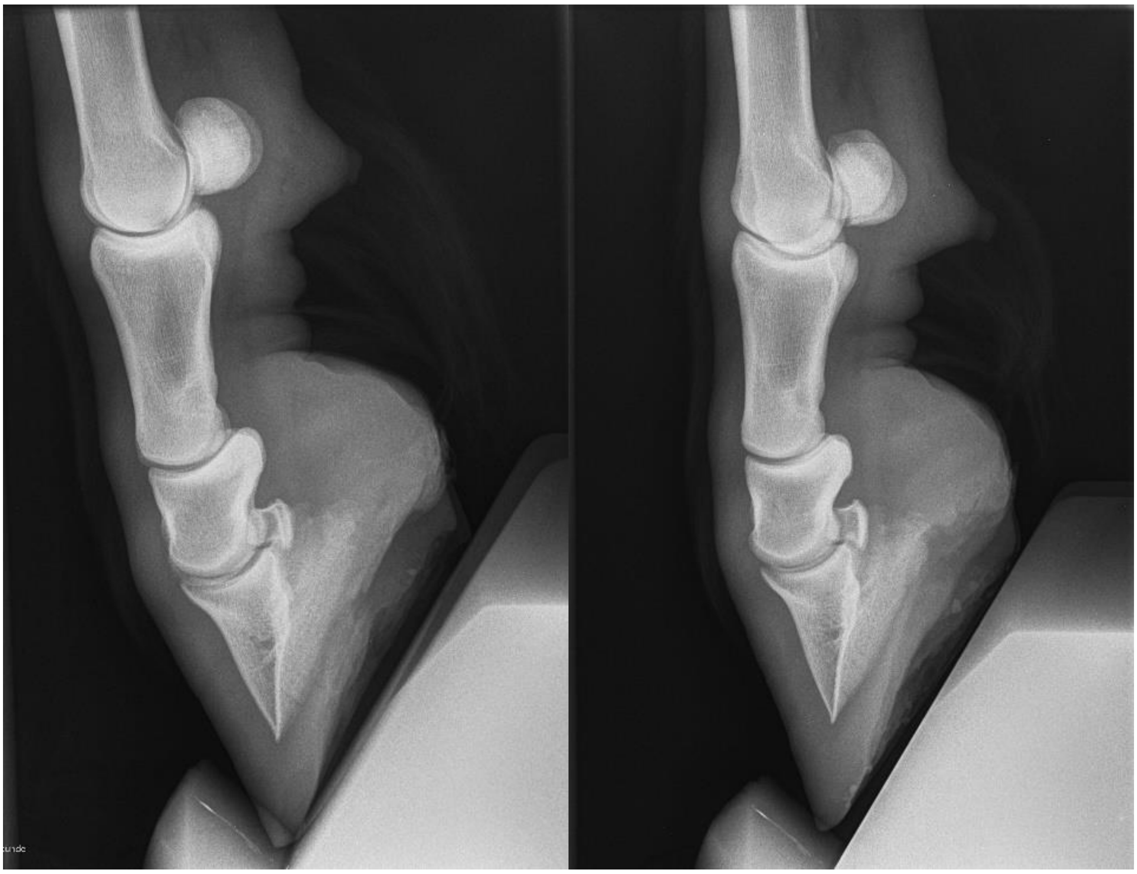
Name: Elivia (64)
Control/ test: control

Age: 5 Y, 6 M

Weight: 189 kg

Height: 100 cm



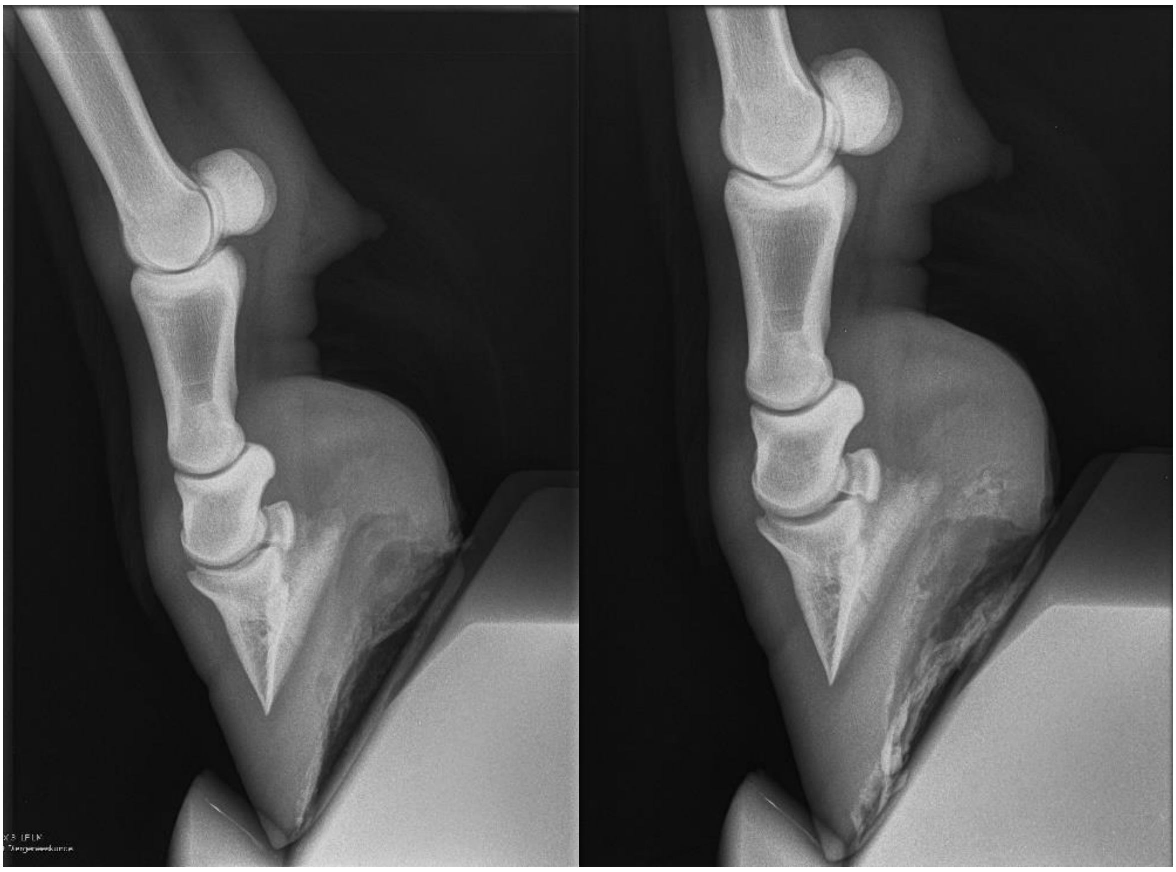


Name: Fabiene (63)
Control/ test: control

Age: 5 Y, 6 M

Weight: 189 kg

Height: 100 cm

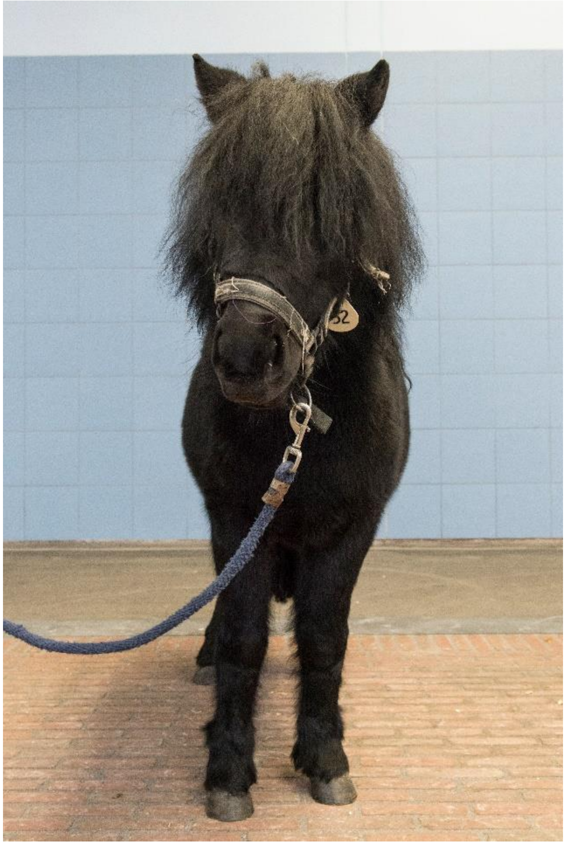


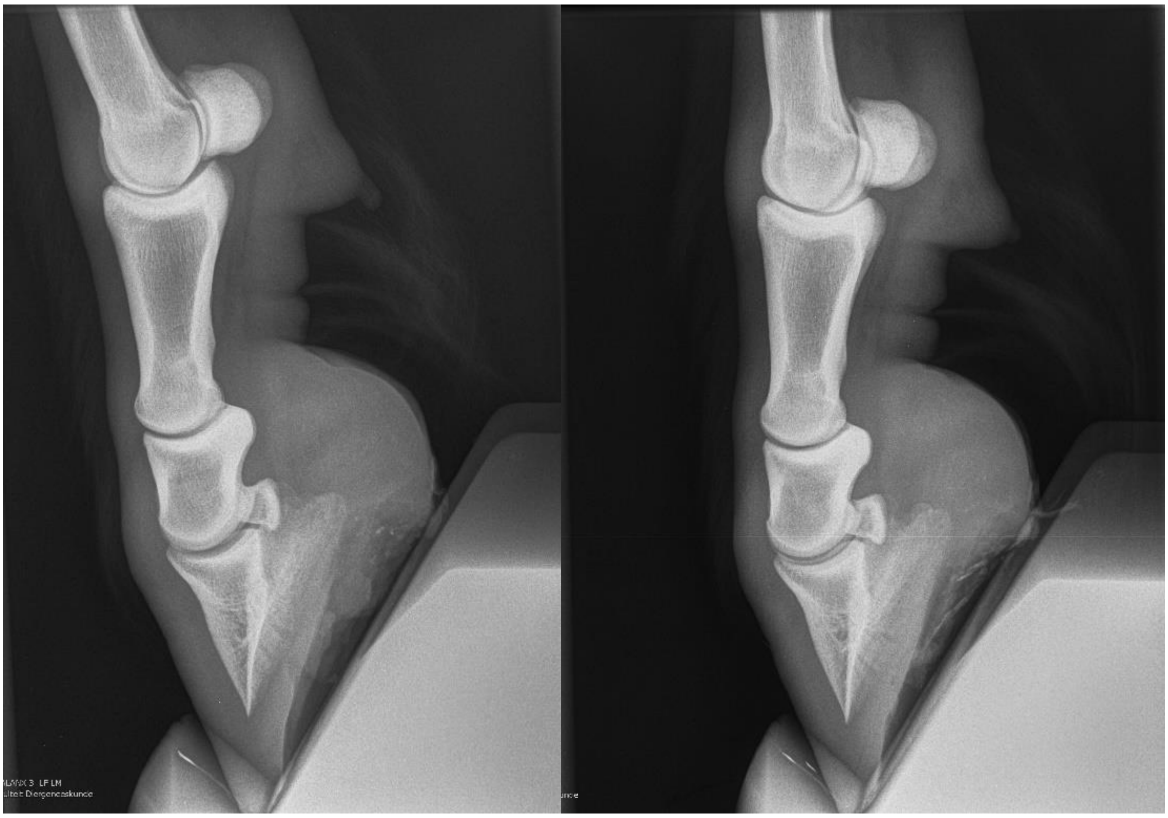
Name: Gwyneth (53)
Control/ test: control

Age: 3 Y, 6 M

Weight: 180 kg

Height: 98.5 cm




LF LM
Diergeneeskunde

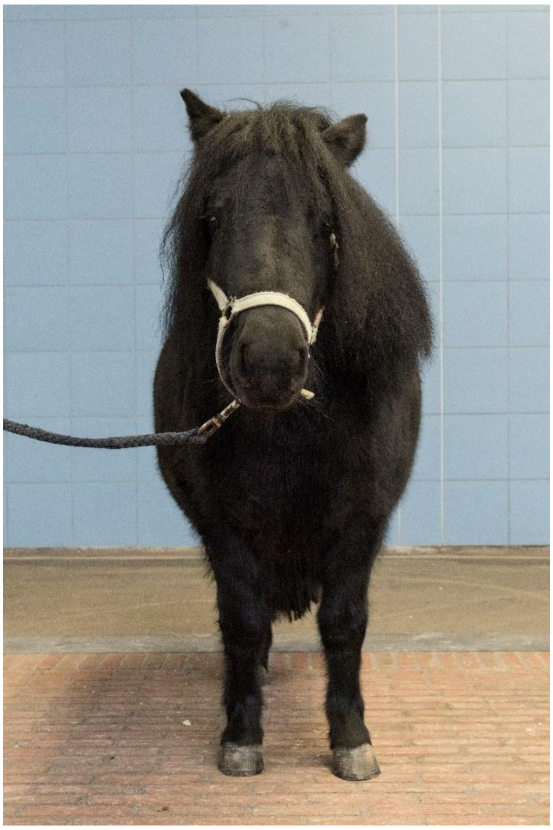
Name: Frederika (74)
Control/ test: test

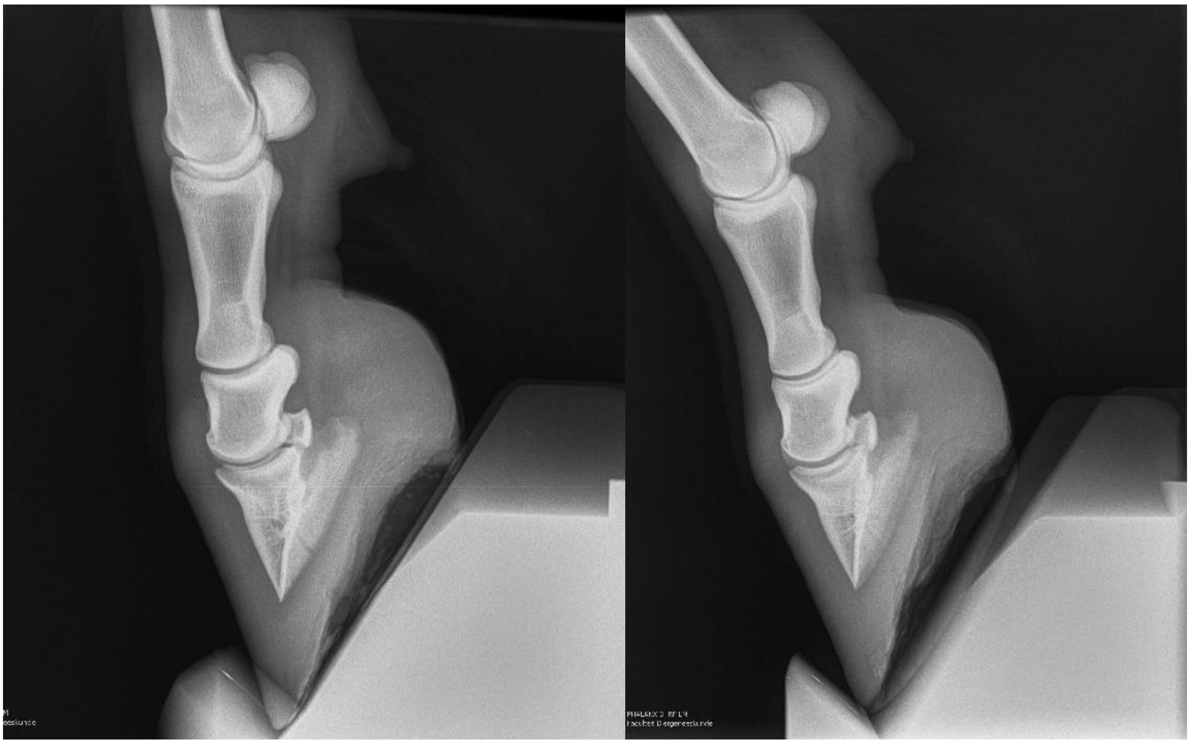
Age: 4 Y, 6 M

Weight: 283 kg

Height: 110 cm





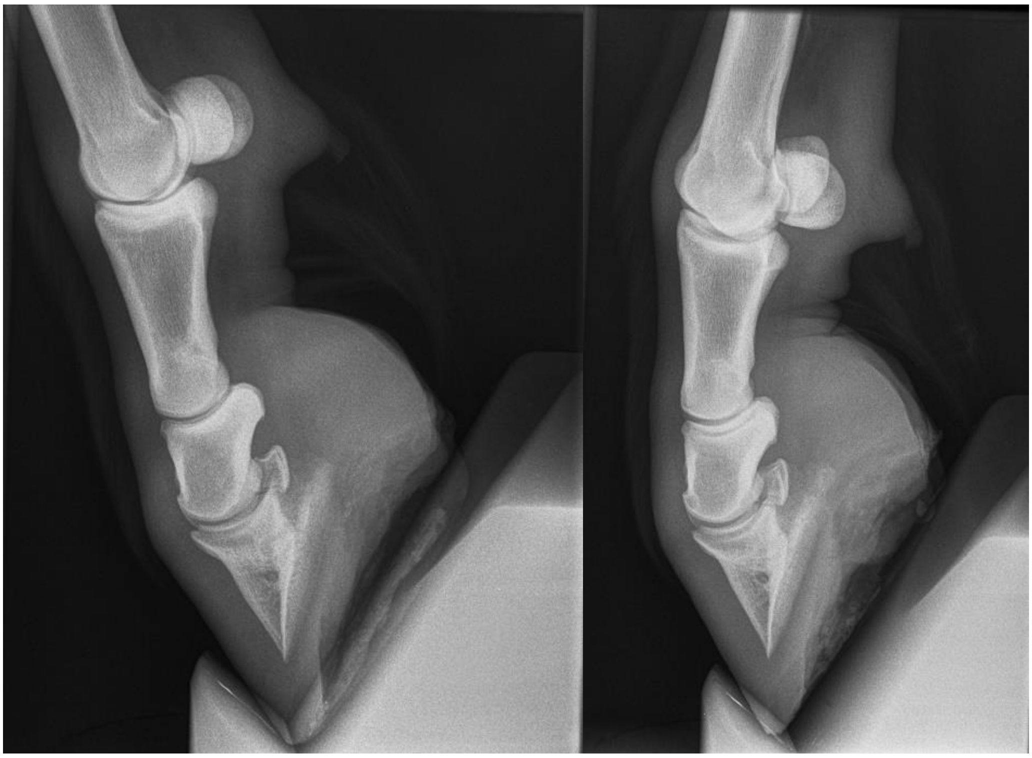

PHALANX 3 RF LM
Faculteit Diergeneeskunde

Name: Florance (48)
Control/ test: control

Age: 4 Y, 6 M

Weight: 191 kg

Height: 104 cm

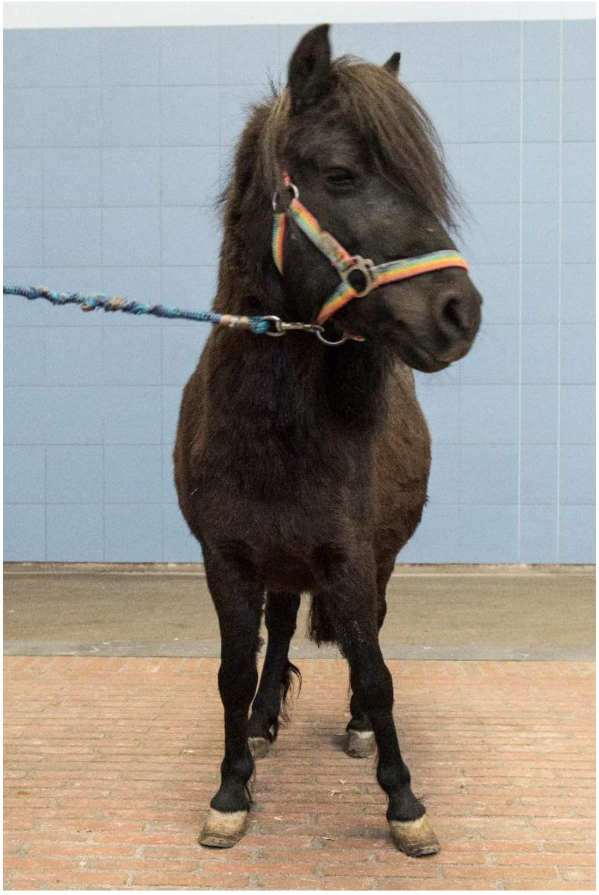


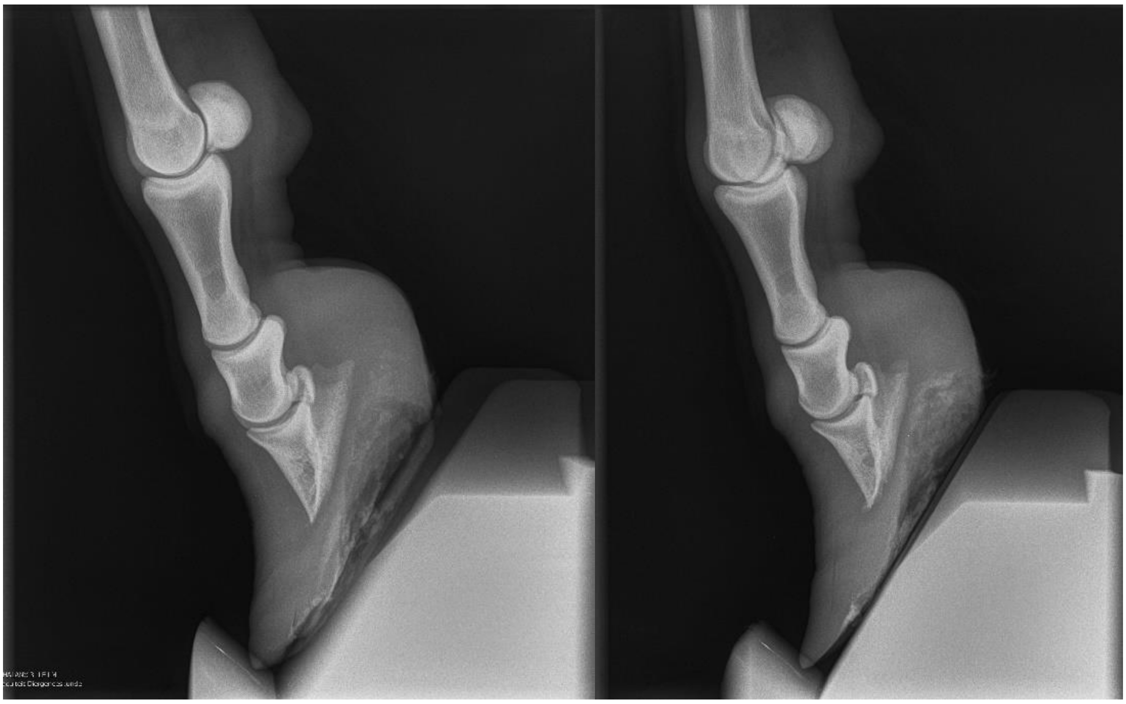
Name: Blacky (59)
Control/ test: test

Age: 5 Y, 7 M

Weight: 174 kg

Height: 105 cm





3. EXTRA M &M: DATA COLLECTION.

1.Protocol of the Q – horse measurements with the Shetland ponies at Thursday the 27th of October 2016.

Animals

Please use the ponies on this -computer assisted random- order:

- 40 C
- 58 T
- 67 C
- 70 T
- 64 C
- 63 T
- 53 C
- 74 T
- 48 C

Protocol

1. Measure the heartrate in rest while the ponies are in the stables and note these measurements.
    - Measure the heartrate with the phonendoscope and count for 60 seconds. Please do this in duplo.

1. Apply the markers on the pony.
2. Start with a neutral measurement to achieve a steady state.
3. Percussion of the left front foot.
4. Measurement 2.
5. Percussion of the right front foot.
6. Measurement 3.
7. Local anesthesia with 1,5 ml Mepivacaine of both front feet.
    - This is based on the article of Bidwell 2004.
8. Wait for 15 minutes.
9. Check the anesthesia by checking the painperception.
10. Percussion of the left front foot.
11. Measurement 4.
12. Percussion of the right front foot.
13. Measurement 5.
14. Remove the markers and put the ponie in the stables.
15. Measure the heartrate in rest while the ponies are in the stables 60 minutes after the administration of Mepivacaïne.

After the full research you have to adjust the management at the maps of the ponies.

4. EXTRA RESULTS: HEARTRATE.

Name	Group (Control/Test)	Heartrate (beats/minute)			
		T=0		T=1	
		Researcher 1	Researcher 2	Researcher 1	Researcher 2
40	C	32	31	49	44
58	T	50	50	52	53
67	C	29	29	40	44
70	T	45	45	50	51
64	C	34	30	40	42
63	T	47	47	50	46
53	C	28	27	39	38
74	T	48	51	48	52
48	C	27	31	48	45
59	T	43	46	52	49

5. EXTRA RESULTS: HOOFPERCUSSION.

Name	Group (Control/Test)	Hoofpercussion before anaesthesia	
		Pain score (1 – 5)	
		Left front feet	Right front feet
40	C	0	0
58	T	3	4
67	C	0	0
70	T	3	4
64	C	0	0
63	T	0	0
53	C	0	0
74	T	1	1
48	C	0	0
59	T	3	2

Name	Group (Control/Test)	Hoofpercussion after anaesthesia	
		Pain score (1 – 5)	
		Left front feet	Right front feet
40	C	0	0
58	T	4	4
67	C	0	0
70	T	2	1
64	C	0	0
63	T	0	0
53	C	0	0
74	T	0	0
48	C	0	0
59	T	2	1

6. EXTRA RESULTS: NSPS VETERINARIAN SCORE.

Name	Group (C/T)	Correctness at walk: hind	Correctness at walk: front	Chest width	Trot: range	Trot: flexibility
		narrow - wide (1 - 9)	**To in – To out (1 - 9)**	narrow - wide (1 - 9)	wide - short (1 - 9)	powerful - rigid (1 - 9)
40	C	3	6	4	5	3
58	T	7	6	7	8	7
67	C	1	6	4	7	7
70	T	5	5	7	6	6
64	C	5	5	5	7	8
63	T	6	6	5	7	5
53	C	3	8	3	4	6
74	T	8	6	5	6	6
48	C	3	6	4	6	6
59	T	6	6	4	4	4

Name	Group (C/T)	Condition	Hoof quality	Shape of the hooves		
		obese (1 - 9)	bands (1 - 9)	narrow - wide (1 - 9)	spiky - round (1 - 9)	steeply - broad (1 - 9)
40	C	3	1	4	8	5
58	T	8	7	4	5	7
67	C	2	1	3	4	6
70	T	9	6	4	4	7
64	C	4	3	4	4	5
63	T	8	5	6	7	6
53	C	4	1	4	7	5
74	T	9	3	4	4	6
48	C	5	1	7	8	5
59	T	5	7	2	3	8

7.EXTRA RESULTS: UKP FARRIER SCORE.

Name	Group (C/T)	Condition	Hoof quality		Shape of the hooves					
		obese (1 - 9)	bands (1 - 9)		narrow - wide (1 - 9)		spiky – round (1 - 9)		steeply – broad (1 - 9)	
			Left	Right	Left	Right	Left	Right	Left	Right
40	C	5	1	1	6	6	5	5	4	4
58	T	9	4	4	8	8	8	8	5	5
67	C	4	1	1	5	5	5	5	6	6
70	T	8	1	1	4	6	3	4	7	7
64	C	5	3	3	5	5	5	5	5	5
63	T	9	3	3	6	6	5	7	5	7
53	C	5	2	2	5	5	5	5	5	5
74	T	9	3	3	6	6	5	5	5	5
48	C	7	1	1	5	5	5	5	5	5
59	T	4	5	4	5	4	3	3	8	8

Name	Group (C/T)	Proximal hoofwall – coffin bone distance		Distal hoofwall – coffin bone distance	
		(mm)		(mm)	
		LF	RF	LF	RFH
40	C	12,1	13,1	11,6	12
58	T	12,6	12,1	13,1	12,9
67	C	10,8	11	10,6	11,4
70	T	13,6	15	16,4	19
64	C	12,5	12,7	11,7	12
63	T	12,3	13,1	11,8	13,1
53	C	12,1	12,1	11,8	11,2
74	T	12,8	12,2	13,2	12,5
48	C	12,2	11,7	11,8	11,8
59	T	13,8	13,6	17,8	17

Name	Group (C/T)	Vertical distance hoof sole – coffin bone / sole thickness		Difference between distal and proximal hoofwall / coffin bone rotation	
		(mm)		(mm)	
		LF	RF	LF	RF
40	C	4,9	8,6	-0,5	-1,1
58	T	11,4	12,3	0,5	0,8
67	C	9,1	7,4	-0,2	0,4
70	T	6,3	9,3	2,8	4
64	C	8,5	8,4	-0,8	-0,7
63	T	13,9	11,4	-0,5	0
53	C	7,4	9,9	-0,3	-0,9
74	T	13	11,1	0,4	0,3
48	C	6,4	9,9	-0,4	0,1
59	T	8,5	7,6	4	3,4