Contents

Abstract

Reasons for performing study

Several methods are used in farriery to estimate the position of internal structures of the hoof using external reference points on the hoof capsule as landmarks. However there is little scientific evidence describing the relationship between the external reference points and the internal structures of the hoof in the current literature.

Aim of the study

To test the ability of the true apex of the frog and the point dividing the cranial third and the middle third of the coronary band, to estimate both the centre of rotation and the centre of articulation of the coffin joint. Furthermore in the second part of the study we tested whether the relationship between internal and external structures of the hoof differed according to whether the limb was loaded or not.

Materials and Method

Nails were used to mark the external reference points in 46 cadaver limbs using 2 different methods. The hooves were then radiographed and the external reference point markers were compared to COR and COA of the coffin joint. Using the results from the cadaveric study, the most precise method using both the length of the coronary band and the true apex of the frog was testet in live horses. The method was tested in an unloaded position with the toe resting relaxed on the ground and in a fully weight bearing position, with the horse standing square.

Results

None of the tested methods in the cadaver limbs were precise in estimation of COR or COA, but all came closer to estimation COA. The most accurate model for estimation of COR from external landmarks was based on the apex of the frog and the length of the coronary band.
The relationship between frog apex and COR could be described with the following model:
*Distance from frog apex to COR= 13.977+0.2235*length of coronary band (in mm)* in the front limb
*Distance from frog apex to COR= 15.2771+0.2235*length of coronary band (in mm)* in the hind limb.
There was no significant difference in dorso-palmar/plantar balance between loaded and unloaded limbs in live horses.
The model for estimation of COR found in the cadaveric study systematically overestimated the distance from frog apex to COR with 6 mm on average in the live horses.
There was a large effect of individual horses.
In live horses the relationship between frog apex and COR could be described as:
*Distance from frog apex to COR= -27.51 + 0.5539*length of coronary band (in mm)* in the front limb
*Distance from frog apex to COR= -8.97 + 0.3837*length of coronary band (in mm)* in the hind limb.

Conclusion

Inter-individual variation is considerable and in order to precisely estimate the COR or COA of the coffin joint radiographs are necessary.

Declaration

This study was performed in collaboration with DVM, Sara Ellingsund Mikkelsen, Vejle Equine Clinique, who performed the radiographic analyses. Furthermore DVM, Jan Dahl, Danish Agriculture and Food Council performed the statistical analyses. The author of this dissertation performed the rest of the work.

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Introduction

Horses are high performance athletes balancing on the edge between maximal performance and overload injuries, and farriers play an important role in keeping them sound, since hoof conformation and balance is a major part of what is determining the biomechanics of the distal limb. The biomechanics of the coffin joint is determined by the moments on either side of the rotational centre of the joint. The length of the lever from the centre of rotation to the point of break over creates the extending moment, which is balanced by the flexing moment created by the tension in the deep digital flexor tendon (Eliashar, 2007).

Empiric and to some degree scientific knowledge tells us that in order to achieve optimal function and minimize the risk of overloading of the hoof and limb, the horse needs to be trimmed and shod in balance (Parks, 2003; Eliashar, 2007). A balanced hoof has a conformation that maximizes its mechanical efficiency (Eliashar, 2007; Hood, 2001). It has been suggested that a balanced foot among other things should have the centre of the weight-bearing surface positioned directly below the centre of rotation of the coffin joint (Butler, 2000; O'Grady, 2009). In order to create a balanced trim without radiographs based on the location of the centre of rotation of the coffin joint, the farrier needs to be able to estimate the position of internal structures, based on external reference points on the hoof.
Different external reference points have been used to estimate the position of internal hoof structures. Among these Russell's x, Duckett's dot and Duckett's bridge, the widest part of the foot, the true apex of the frog and specific measured points on the coronary band. They are empirically developed methods based on the experience of the farriers who developed them.

In the current scientific literature there is little evidence describing the relationship between the external reference points and the internal structures of the hoof. A few self-published studies point out that the widest part of the hoof is difficult to define and that the relationship to the COR is not constant (Craig, 2015; Ovnicek, 2008).
Furthermore the terms centre of the coffin joint; centre of pressure; centre of rotation and centre of articulation are not always clearly defined when the methods are discussed. In this thesis the terms centre of articulation and centre of rotation are used. The centre of articulation is defined as the middle of the articular surface of P3 (fig. a) and the centre of rotation is defined as the point on P2 around which the coffin bone rotates (fig. b).

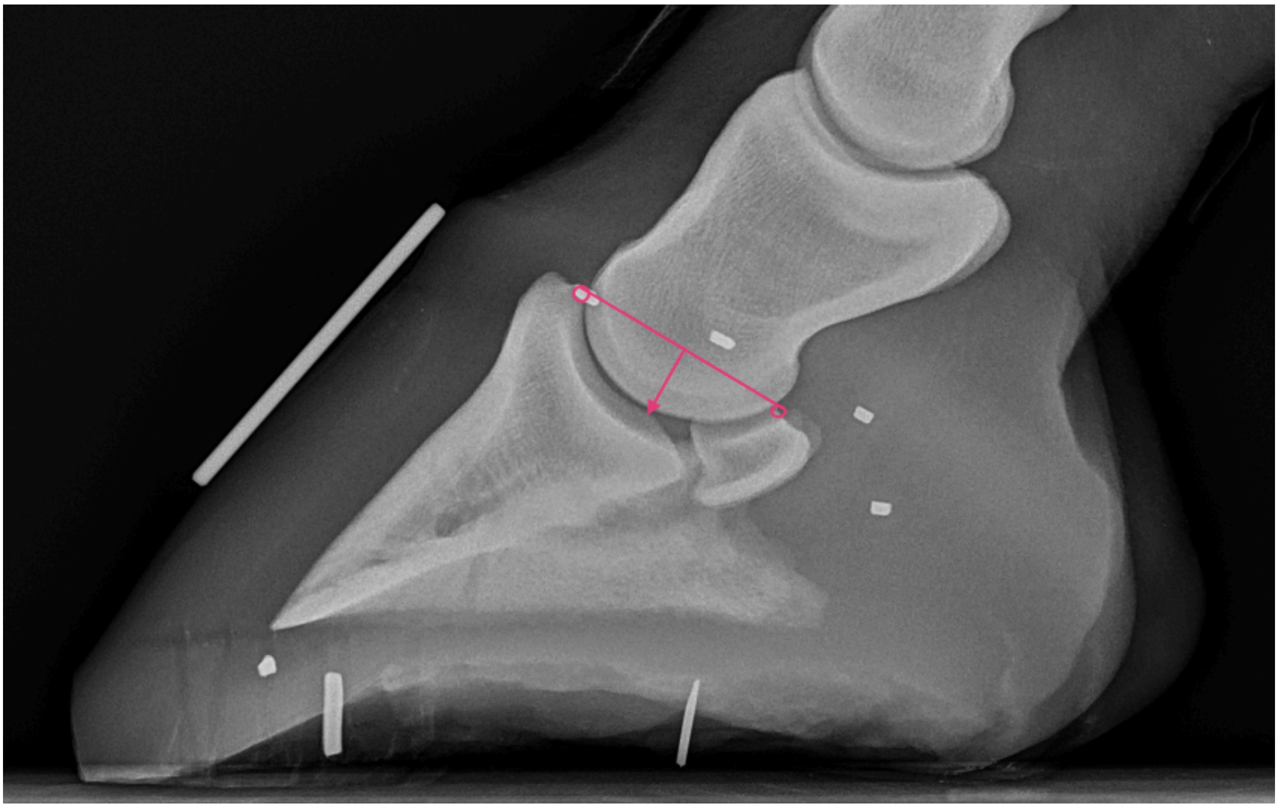


Figure a: Centre of articulation (COA) (arrow)

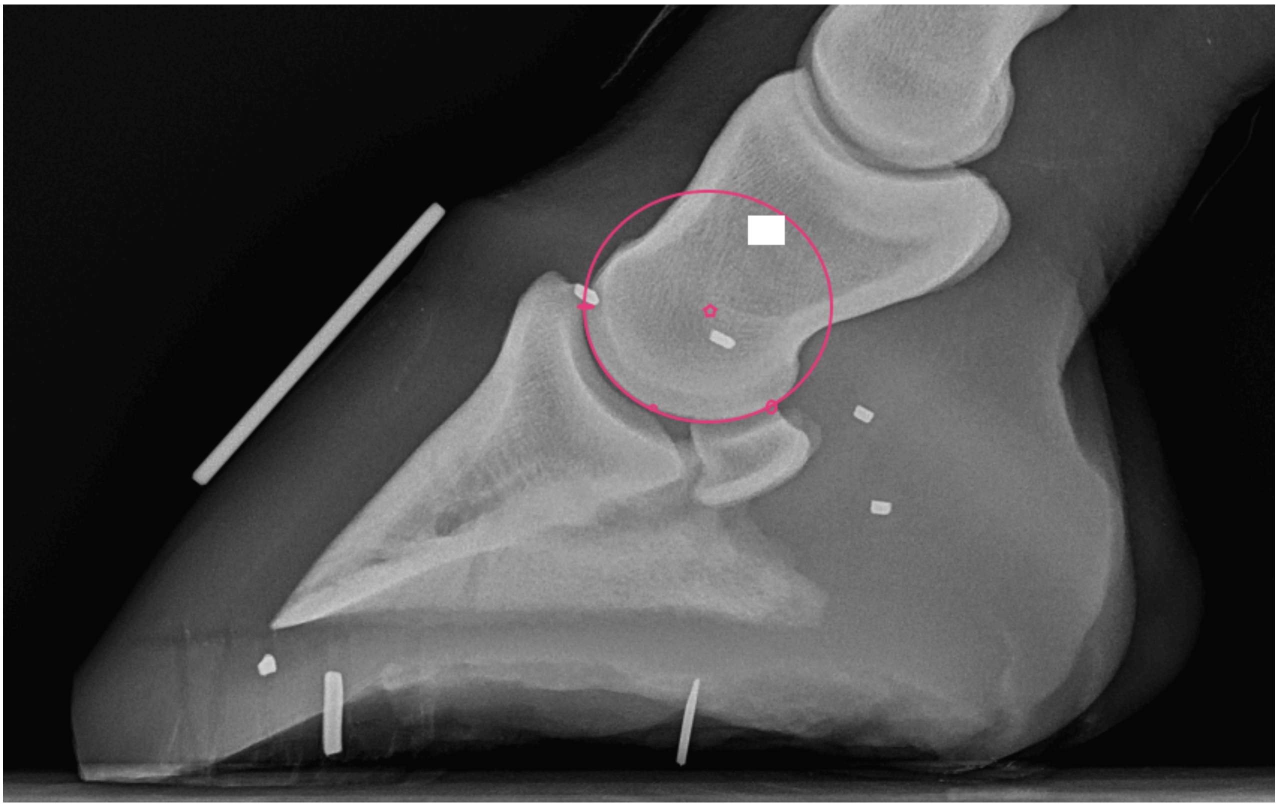


Figure b: Centre of rotation (COR)(star).

The true apex of the frog (where the horn of the frog blends with the solar horn) and measured points on the coronary band seem to be landmarks that are fairly reproducible and relatively easy to recognise for the farrier. This thesis will investigate the relationship between these points and the centre of rotation and the centre of articulation of the coffin joint in order to decide whether they are reliable as guidelines for trimming and shoeing.

The apex of the frog as an external landmark

Duckett (1990) uses the apex of the frog to locate what he calls the anatomical centre of P3. He claims that a point 3/8" (9,5 mm) back (in the average sized horse) from the true apex of the frog is directly beneath the anatomical centre of P3. In small horses it is a little closer to the apex of the frog and in larger horses it is a little further from the apex of the frog. Duckett's bridge is a line caudal to Duckett's dot across the widest part of the foot. This line is said to be directly below the centre of rotation of the coffin joint. Duckett suggests that the bridge in the well-balanced hoof will divide the weight-bearing surface into two equal halves. In Gene Ovnicek's paper *Applying the Equine Digit Support System* (1996) he claims that a point 3/4" (19 mm) caudal to the true apex of the frog, coincides with the widest part of the hoof, the termination of the bars and the centre of articulation. This is based on findings in feral horses.

The coronary band as an external landmark

Jim Ferrie (2007) uses the length of the coronary band as a reference for finding the centre of the coffin joint. His theory is that the centre of the coffin joint is at the transition between the cranial and middle third of the coronary band distance from toe to heel. This method takes into account the size of the horse (Figure c: Identification of the centre of the coffin joint according to Ferrie (2007).

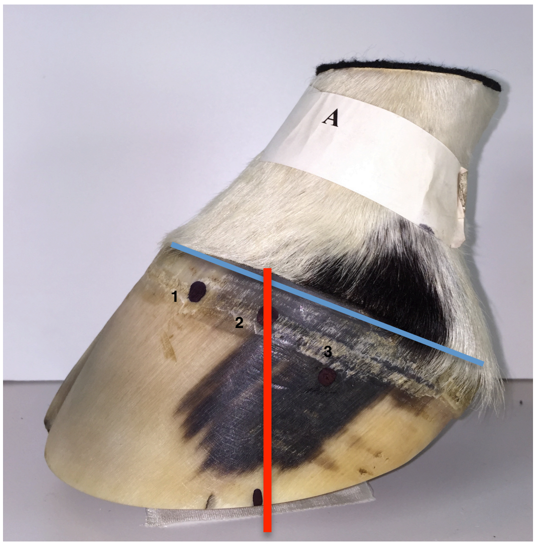


Figure c: Identification of the centre of the coffin joint according to Ferrie (2007).

Aim of the study

In this study the aim was to test the ability of the true apex of the frog and the point dividing the cranial third and the middle third of the coronary band, to estimate the centre of rotation and the centre of articulation of the coffin joint in order to establish if these external reference points have a precise and constant relationship with internal structures of the hoof. Radiographs were used to confirm the position of the centre of rotation and the centre of articulation. Furthermore in the second part of the study we tested whether the relationship between internal and external structures on the hoof differed according to whether the limb was loaded or not.

Materials and methods

Cadaveric study

23 front limbs and 23 hind limbs from an abattoir were used. None of the limbs were shod. Several of the hooves showed signs of neglected hoof care (Figure d). There was no registration of whether horses contributed with one or four legs. All legs were cut proximally on the metacarpus or metatarsus (standard procedure at the abattoir). All 46 legs were used in all test situations.

Figure d: 46 abattoir limbs.

Method 1a:
Untrimmed hooves.
The hoof was placed on a horizontal surface and a calliper was placed on the coronary band from the centre of the toe to the bulbs of the heels. This was recorded as the total coronary band distance. A line was dropped perpendicularly to the ground from the point dividing the cranial and the middle 1/3 of the total coronary band distance. The line was continued across the solar surface to the middle of the frog where a small nail-marker was inserted.

The hoof was placed on a wooden block and a 5 cm calibration-marker was placed centrally on the dorsal hoof wall. The hoof was not loaded, as the lack of tendon support would prevent a natural loading situation. One lateral radiograph was taken of each hoof.

Method 1b:
This method was identical to method one, except that the author (AWCF certified farrier) had trimmed the hooves before measurements and placing of the nail. The following trimming procedure was used (Figure e):

- Removal of loose solar horn
- Trimming the frog back to the heel bulb
- Cleaning out the sole, leaving the bars strong for maximal support
- Trimming the hoof from toe to heel to the widest part of the frog
- Removal of hoof wall flares

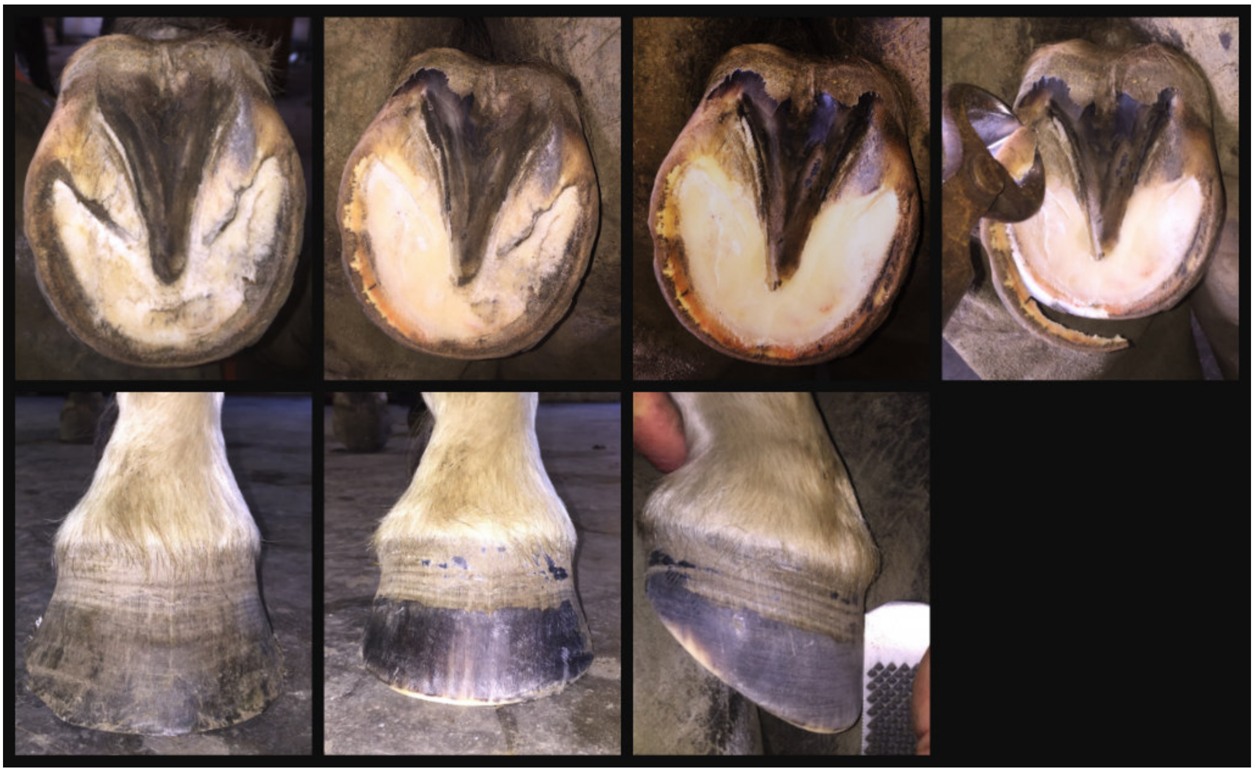


Figure e: From top left to bottom right: Untrimmed hoof; loose solar horn has been removed and the frog trimmed back to the heel bulb in the left half of the hoof; the sole has been cleaned out and the bars left strong for maximal support; the hoof is trimmed from toe to heel; before removal of hoof wall flares ; After removal of hoof wall flares..

Method 2:
On the trimmed hoof a nail was placed 19 mm (3/4”) caudal to the true apex of the frog. The radiographic protocol was the same as in method 1a and 1b.

All radiographic images were analysed in eFilm.
The centre of rotation of the coffin joint was measured using the technique described by Craig (2001, 2003) where a circle is fitted to the distal end of P2, by letting it touch 3 points on the joint surface of the coffin joint (Figure b, page 5). The centre of articulation was measured using the technique described by Ovnicek (2008) where a line is drawn between the most proximal part of the distal sesamoid bones and the extensor process. In the middle of this line a second line perpendicular to the first is continued to the articular surface of the coffin joint. This marks the centre of articulation (Figure a, page 5).

All images were calibrated before analysis. On all hooves the horizontal distance from a vertical line perpendicular to the ground surface of the hoof through the centre of rotation (COR) and the centre of articulation (COA) to the nail-marker in the frog was recorded on all hooves (Figure f).

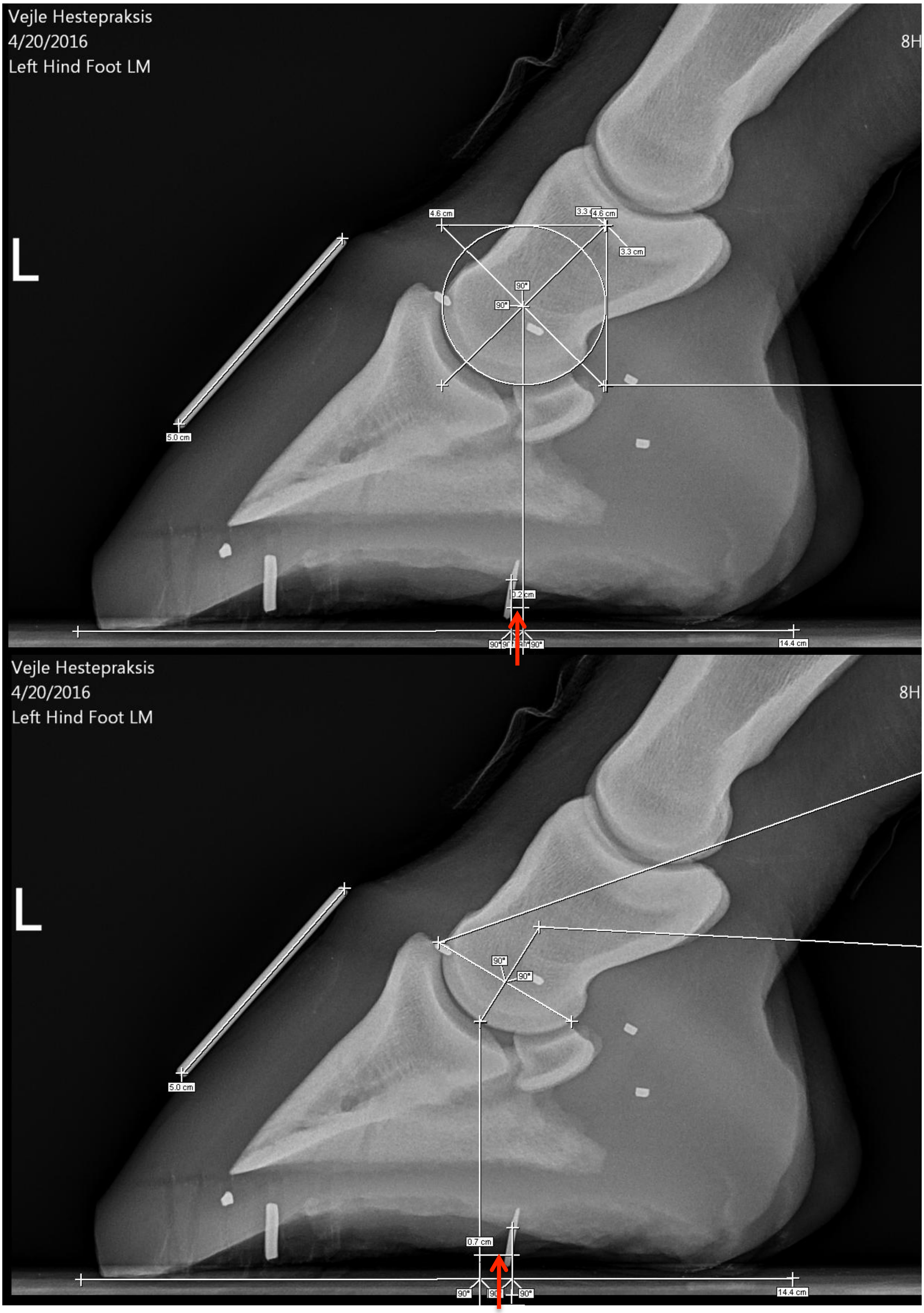


Figure f: top: Measurement of distance from COR to nail marker; bottom: Measurement of distance from COA to nail marker.

Live horse study

The model found to be most precise in estimation COR in the cadaveric study was tested in live horses. This was the *distance from frog apex to COR= 13.977+0.2235*length of coronary band (in mm)* in the front limb and the *distance from frog apex to COR= 15.2771+0.2235*length of coronary band (in mm)* in the hind limb.

The method was tested in an unloaded position with the toe resting relaxed on the ground and in a fully weight bearing position, with the horse standing square (Figure g).

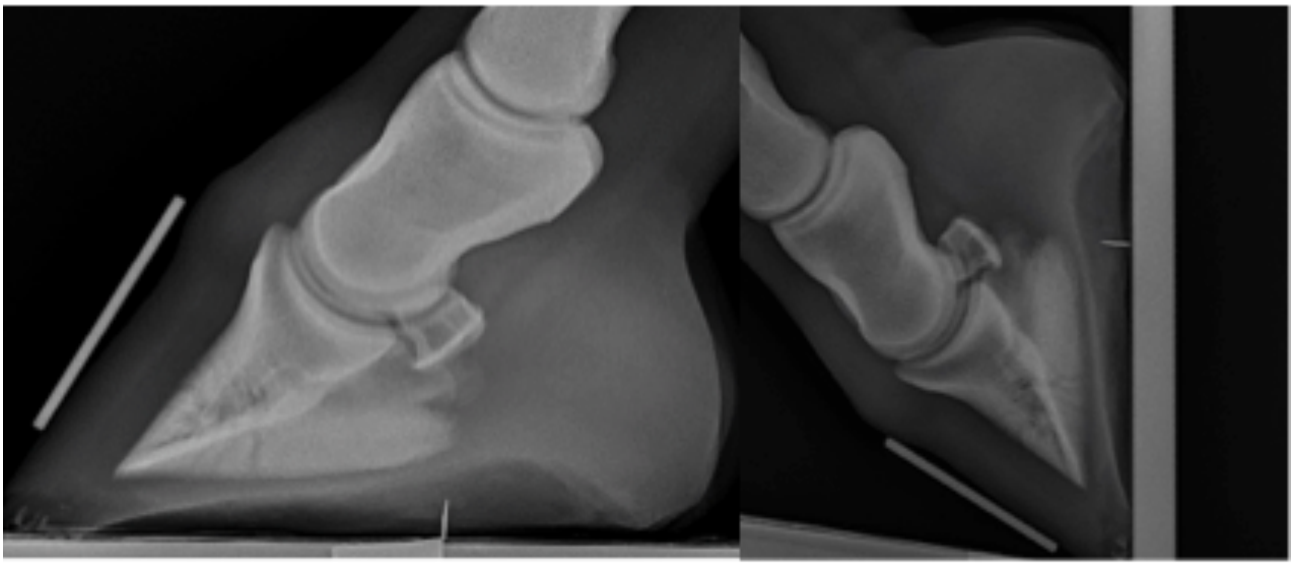


Figure g: Radiographs of the same limb loaded and unloaded.

Six horses contributed each with all four legs. The age range was 2-17 years of age and the size ranged from 135 cm to 172 cm.

Radiographs were taken and analysed as described in the cadaveric study.

Results

Test of repeatability for COR method

The circle fitted to the coffin joint in order to decide the COR was measured on three different radiographs (method 1a, 1b and 2). The mean diameters of the circles are shown in table 1. There is a small, but significant difference in the diameter of the circles for the three different measurements (p=0.0010).

Table 1: Mean diameter, standard deviation, sum and minimum and maximum values of the circles fitted to the coffin joint in the three different radiographs (method 1a, 1b and 2) for each leg.

Variable	N	Mean diameter	Std. Dev.	Sum	Minimum	Maximum
Method 1b (Coronary band, trimmed hoof)	46	31.20	3.42	1435	24	38
Method 1a (Coronary band, untrimmed hoof)	46	31.85	3.27	1465	25	38
Method 2 (Apex of frog)	46	30.87	3.53	1420	24	38

The correlations between the three different measurements were high (Table 2).

Table 2: Pearson Correlation Coefficients for the circles fitted to the coffin joint in the three different radiographs (method 1a, 1b and 2) for each leg.

Pearson Correlation Coefficients, N = 46			
	Method 1 b	**Method 1a**	**Method 2**
Method 1b	1.00000	0.83567	0.92851
Method 1a	0.83567	1.00000	0.84177
Method 2	0.92851	0.84177	1.00000

Estimation of COR

There was no significant effect of limb (front or hind), but significant difference between the methods when estimating the centre of rotation ($p<0.0001$) (Table 3).

Table 3: Mean deviation from nail-marker to COR.

Mean deviation from centre of rotation		
Effect	**Leg**	**Mean deviation from COR (mm)**
Method 2 (Apex of frog)	**Hind**	20.09
Method 2 (Apex of frog)	**Front**	19.74
Method 1b (Coronary band, trimmed hoof)	**Hind**	5.09
Method 1b (Coronary band, trimmed hoof)	**Front**	2.52
Method 1a (Coronary band, untrimmed hoof)	**Hind**	7.57
Method 1a (Coronary band, untrimmed hoof)	**Front**	6.48

Because of the lack of significance in the standard deviations the hind and front limbs were pooled for further analysis regarding the estimation of COR. The research showed that method 2 had the largest mean distance from the nail-marker to COR (19.9 mm), but had the smallest standard deviation (4.9 mm), whereas method 1b had the smallest mean distance from nail-marker to COR (3.8 mm), but also had the largest standard deviation (5.8 mm) (table 4 and 5). The differences in standard deviation between the different methods were not significant.

Table 4: The deviations in mm from nail-marker to COR (0 on the y axis).

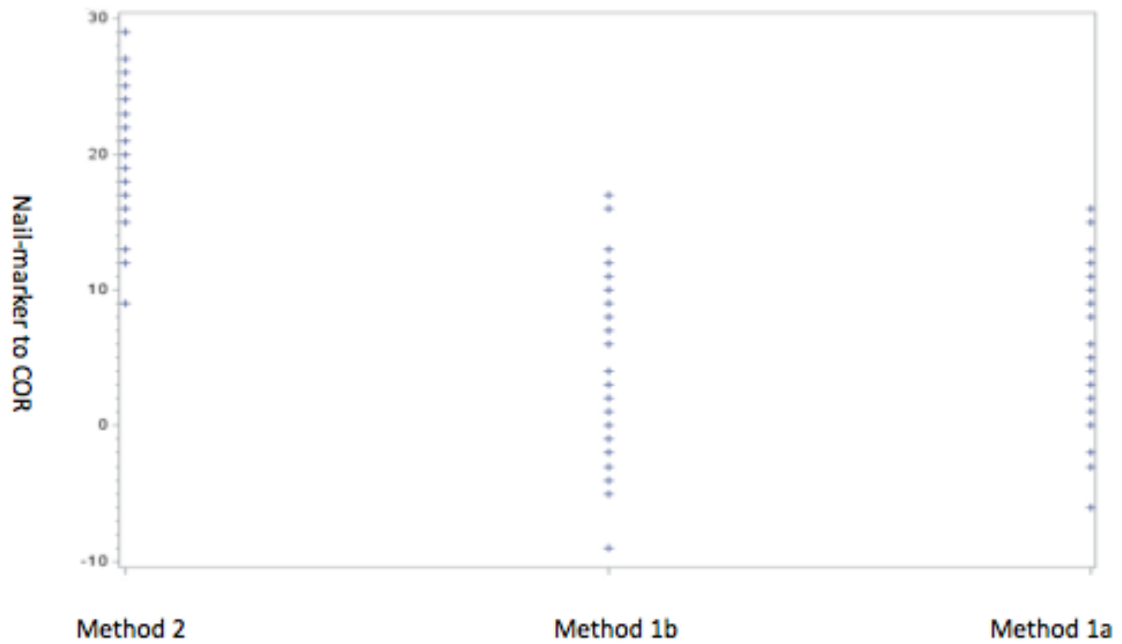


Table 5: Mean, standard deviation, minimum and maximum values for the distance from nail-marker to COR for method 1a, 1b and 2.
All measurements are in mm.

Analysis Variable: Nail-marker to COR (method 2)				
N	Mean	Std. Dev.	Minimum	Maximum
46	19.91	4.88	9	29

Analysis Variable: Nail-marker to COR (method 1b)				
N	Mean	Std Dev.	Minimum	Maximum
46	3.80	5.80	-9	17

Analysis Variable: Nail-marker to COR (method 1a)				
N	Mean	Std. Dev.	Minimum	Maximum
46	7.02	5.65	-6	16

Estimation of COA

There was no significant effect of limb (front or hind), but significant difference between methods when estimating the centre of articulation ($p<0.0001$) (Table 6).

Table 6: Mean deviation from nail-marker to COA.

Mean deviation from centre of articulation		
Effect	**Leg**	**Mean deviation from COA (mm)**
Method 2 (Apex of frog)	**Hind**	12.35
Method 2 (Apex of frog)	**Front**	12.78
Method 1b (Coronary band, trimmed hoof)	**Hind**	-1.70
Method 1b (Coronary band, trimmed hoof)	**Front**	-4.04
Method 1a (Coronary band, untrimmed hoof)	**Hind**	0.39
Method 1a (Coronary band, untrimmed hoof)	**Front**	-0.04

Because of the lack of significance in the standard deviations the hind and front limbs were pooled for further analysis regarding the estimation of COA. Method 2 had the largest mean distance from nail-marker to COA (12.6 mm), but also had the smallest standard deviation (3.6 mm). Method 1a had the smallest mean distance from nail-marker to COA (0.2 mm), but had a large standard deviation (5.0 mm). Method 1b had the largest standard deviation (6.1 mm) (Table 7 and Table 8). The differences in standard deviation between the different methods were significant (p=0.02).

Table 7: The deviations in mm from nail-marker to COA (0 on the y axis).

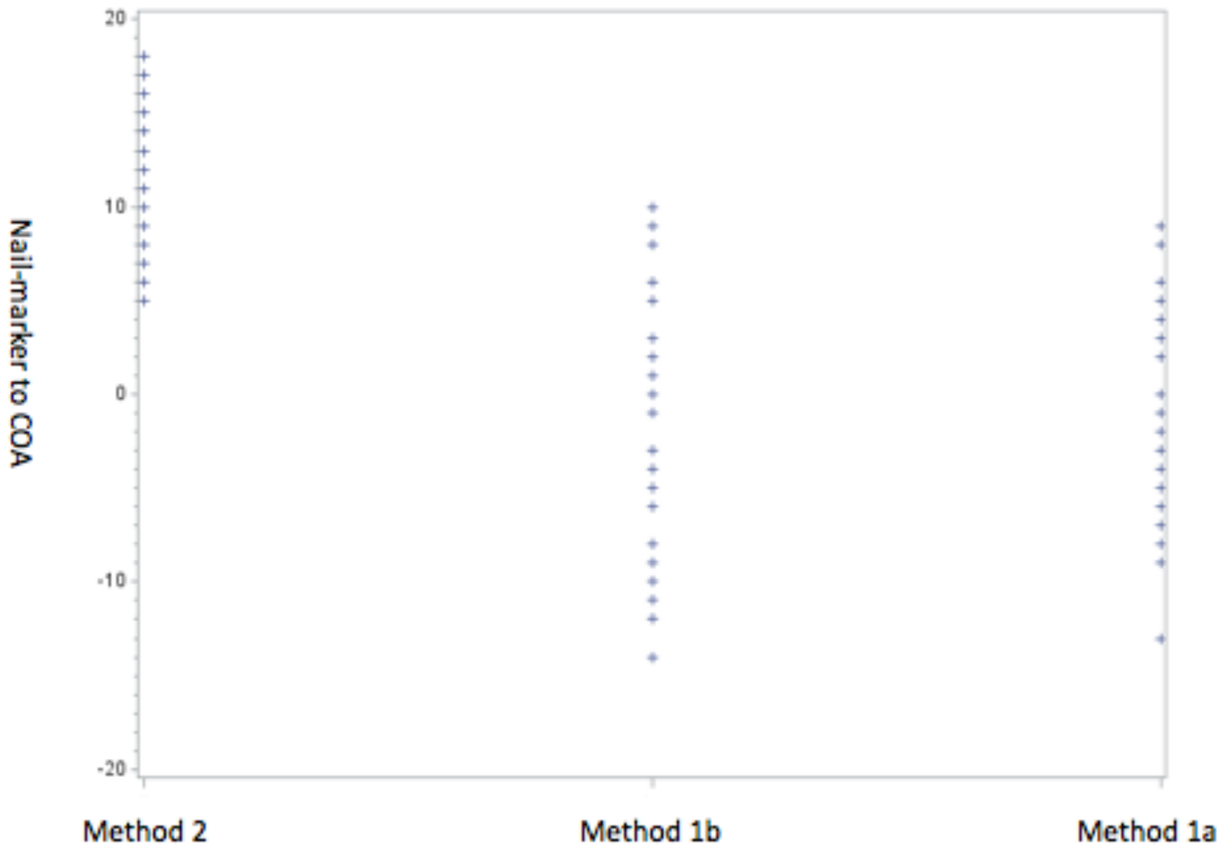


Table 8: Mean, standard deviation, minimum and maximum values for the distance from nail-marker to COA for method 1a, 1b and 2.
All measurements are in mm.

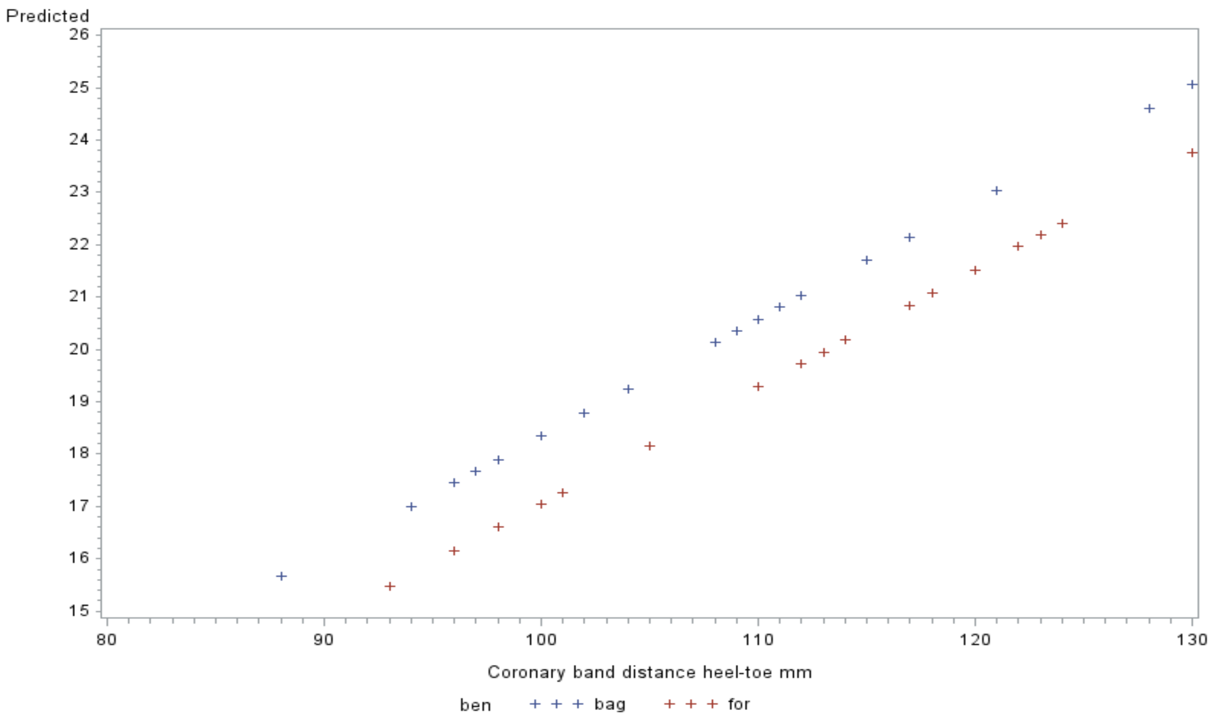
Analysis Variable: Nail-marker to COA (method 2)				
N	Mean	Std Dev.	Minimum	Maximum
46	12.57	3.57	5	18

Analysis Variable: Nail-marker to COA (method 1b)				
N	Mean	Std Dev.	Minimum	Maximum
46	-2.87	6.10	-14	10

Analysis Variable: Nail-marker to COA (method 1a)				
N	Mean	Std Dev.	Minimum	Maximum
46	0.17	5.04	-13	9

All methods came closer to estimating the centre of articulation than the centre of rotation. In method 2 the size of the horse was not taken into account. When using the length of the coronary band as an explanatory variable in method 2, the mean distance from the nail-marker to COR decreased. For every mm the length of the coronary band increased the predicted distance from nail-marker to COR increasesd by 0.22 mm (Table 9). The difference in front and hind limbs was not significant. When using this modification of method 2, the standard deviation decreased significantly from 4.94 to 4.34.

Table 9: Predicted nail-marker to COR distance (mm) with coronary band distance as an explanatory variable.



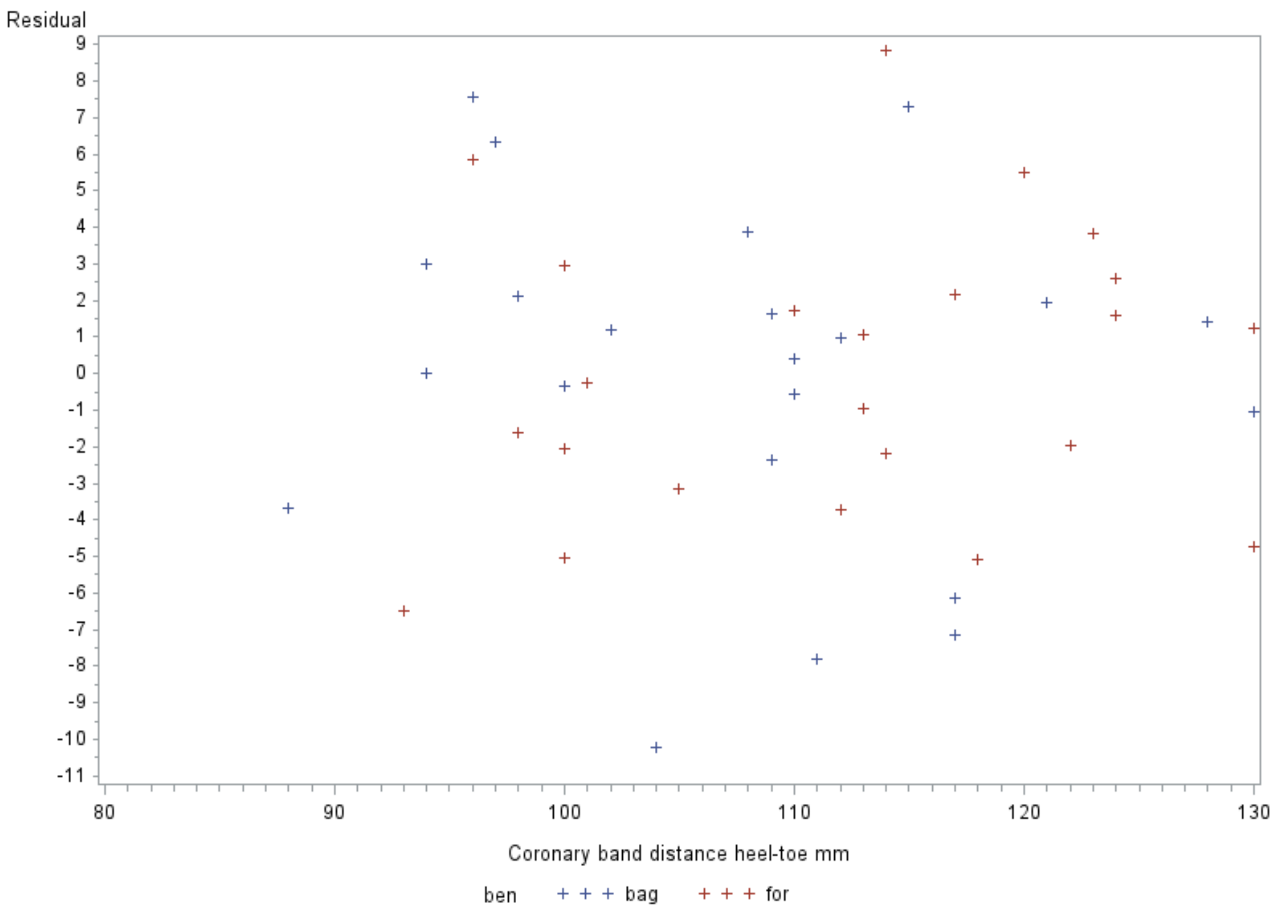
The relationship could be described with this model:
*Distance from nail-marker to COR= -5.0230+0.2235*length of coronary band (in mm)* in the

front limb
*Distance from nail-marker to COR= -3.7229+0.2235*length of coronary band (in mm)* in the hind limb.

Because the nail-marker was placed 19 mm caudal to the apex of the frog, the relationship between the apex of the frog, and the COR could be described as:
*Distance from frog apex to COR= 13.977+0.2235*length of coronary band (in mm)* in the front limb
*Distance from frog apex to COR= 15.2771+0.2235*length of coronary band (in mm)* in the hind limb.

Table 10 shows residual values between 0 and 10.5 mm when using the predicted values for the distance from the nail-marker to COR, with the length of the coronary band as an explanatory variable.

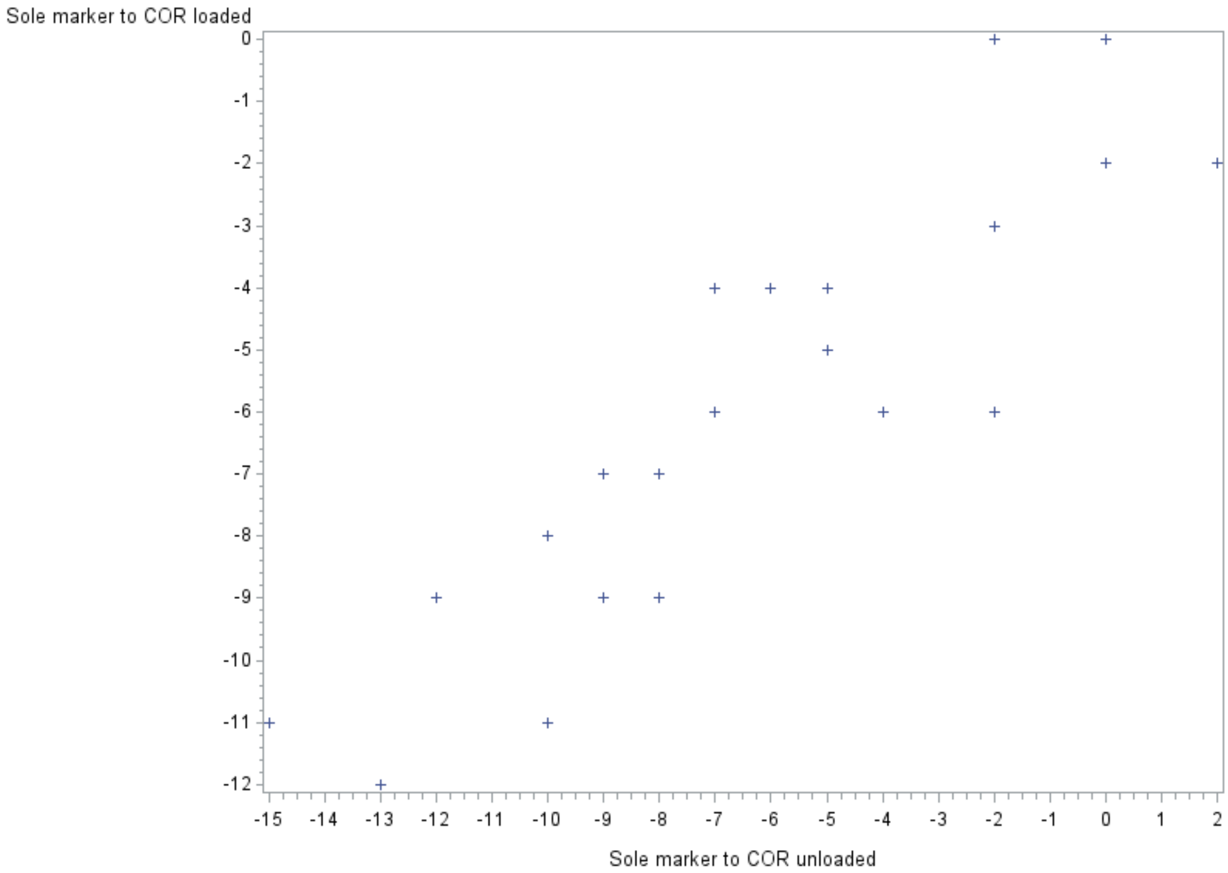
Table 10: Residual values for the calculated distance from frog apex to COR.



Live Horse Study

There was a very high correlation between loaded and unloaded limbs (Pearsson correlation coefficient=0.91), meaning that a hoof with a short distance from sole marker to COR in the unloaded limb, would also have a short distance from sole marker to COR in the loaded limb. This confirms a predictable relationship between loaded and unloaded distance from sole marker to COR (Table 11).

Table 11: Relationship between loaded and unloaded limbs (correlation 0,91).



There was no significant effect of whether the limbs were loaded or not and no significant effect of leg type (fore or hind limb), but there was a significant effect of coronary band distance (Table 12) and this effect was different for front and hind limb (Table 13).

Table 12: Test of significance of coronary band distance, loaded or unloaded and limb type.

Effect	Limb	load	Estimate	Standard Error	Pr > |t|	Lower	Upper
Intercept			-32.3990	8.8543	0.0146	-55.1597	-9.6384
coronary_band_distan			0.2387	0.08103	0.0054	0.07479	0.4026
load		**Yes**	0.4167	0.7056	0.5582	-1.0105	1.8438
load		**No**	0	.	.	.	.
Limb	**fore**		0.5048	0.7148	0.4843	-0.9411	1.9507
Limb	**hind**		0	.	.	.	.

Table 13: Test of significant influence of coronary band distance on fore and hind limbs.

Solution for Fixed Effects						
Effect	**Limb**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
Intercept		-8.9693	9.8287	5	-0.91	0.4033
coronary_band_distan		0.3837	0.09003	39	4.26	0.0001
Limb	**fore**	-18.5514	5.5902	39	-3.32	0.0020
Limb	**hind**	0	.	.	.	.
coronary_band_d*Limb	**fore**	0.1702	0.05170	39	3.29	0.0021
coronary_band_d*Limb	**hind**	0	.	.	.	

Table 14 shows the effect of the individual horses ($p<0.0001$).

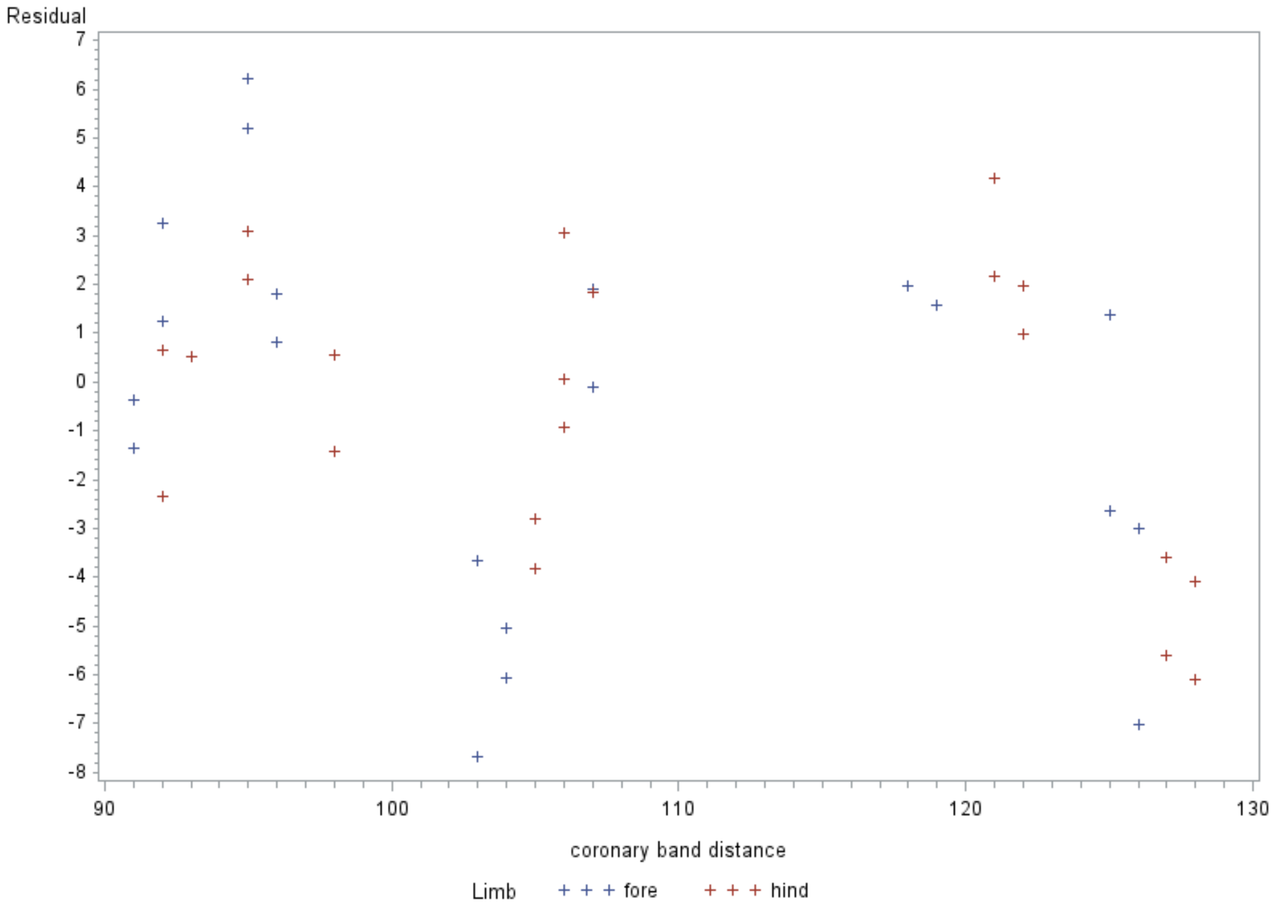
Table 14: The deviation of the individual horses from the predicted value.

Solution for Random Effects							
Effect	**horse**	**Estimate**	**Std Err Pred**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
horse	**1**	2.4978	1.6641	0.1414	0.05	-0.8682	5.8637
horse	**2**	1.4384	1.7275	0.4101	0.05	-2.0558	4.9326
horse	**3**	-3.3047	1.3427	0.0184	0.05	-6.0206	-0.5887
horse	**4**	1.4422	1.3198	0.2812	0.05	-1.2274	4.1118
horse	**5**	0.7100	1.7328	0.6842	0.05	-2.7950	4.2151
horse	**6**	-2.7837	2.0358	0.1793	0.05	-6.9015	1.3341

The most precise model in the live horses was found to be:
Distance from frog apex to COR=-27.51 + 0.5539 length of coronary band (in mm)* in the front limb (standard deviation 2.7).
Distance from frog apex to COR=-8.97 + 0.3837* *length of coronary band (in mm)* in the hind limb (standard deviation 1.6).

Table 15 shows the residual values when using the models above. The residual values ranged from 0 to 8.

Table 15: Residual values for the calculated distance from frog apex to COR



Discussion

Cadaveric study

Craig (2003) has described how the centre of a circle fitted to the distal end of P2 represents the COR of the coffin joint. Ascribing a fitted circle to a joint could be a source of error, and to the authors knowledge there is no previous test of the repeatability and reliability of this method of finding the COR comparing three different lateromedial radiographs. However, the small differences in mean circle diameter and the high correlations between the measured circle diameters in the different radiographs indicated that in this study, the method was reliable. The mean diameter for the three different radiographs was within one millimetre and this small difference could be due to uncertainty of measurement.

This study confirms the findings in former studies trying to estimate the centre of rotation or centre of articulation (Craig, 2015; Conroy, 2011). The large standard deviations show that the inter-individual variation in hoof anatomy is considerable. All methods in the cadaveric study came closer to estimating COA than COR. There seems to be no clear agreement in the literature as to whether the used landmarks are referring to COA, COR or simply to a point around which to create balance or symmetry when trimming the horse. In the authors hands the *Shoeing around the coffin joint* method (Ferrie, 2007) has worked really well in the population of warm blood horses that are the primary population in his daily practice. The author finds that the method optimizes the biomechanical efficiency of the distal limb of the horses by keeping the toe short and by giving sufficient support to the palmar/plantar part of the hoof. The results of this study did however indicate that the point, around which the hoof is balanced using this method, on average, is positioned 7 mm (untrimmed hoof; trimmed hoof 3.8 mm) cranial to COR, but quite close to COA. The fact that this author uses the method *shoeing around the coffin joint* and finds that the method pulls the toe and the weight bearing surface as palmarly/plantarly as possible, raises the question of whether it is a realistic goal to trim/shoe all horses with 50 % of the weight bearing surface palmar/plantar to the COR. In the literature this is often mentioned as the optimal balance (Butler, 2000; O'Grady, 2009), but there seems to be no published data confirming this in sports horses. This author is convinced that pulling the toe further back will potentially result in lame horses due to trimming too close to sensitive tissue.

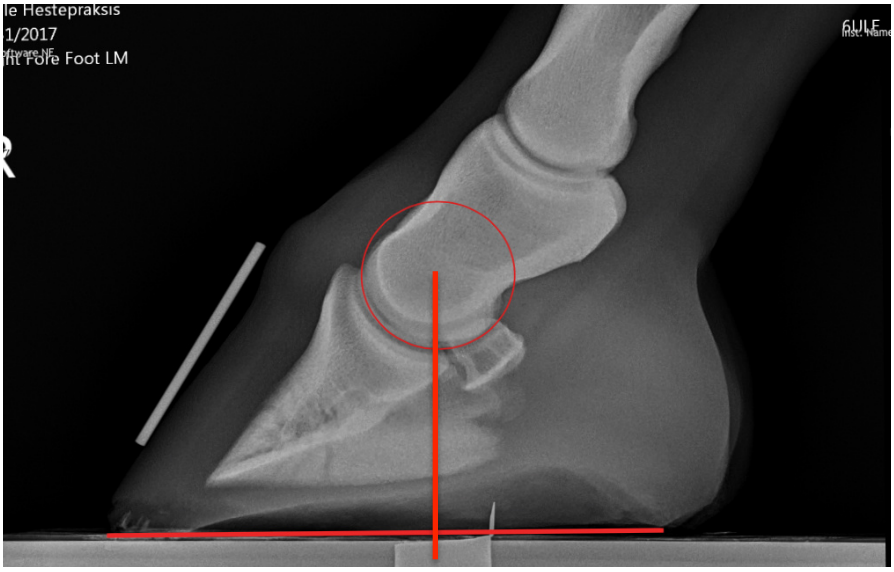


Figure h: A trimmed hoof with a 60:40 ratio of the weight bearing surface in relation to COR.

Even though it might be more realistic to balance the weight bearing surface equally around COA , COR is biomechanically the most interesting point. This is the point around which the leg rotates and therefore plays a major part in the distal limb biomechanics. In this study the smallest standard deviation and therefore the most accurate estimation of COR was when method 2 was used. The nail-marker in this method was placed 19 mm caudal to the apex of the frog. The mean distance from this point to COR was 20 mm. This means that in this cadaveric study the most precise estimation of COR would have been a point 39 mm caudal to the apex of the frog. According to Duckett (1990), size does influence the relationship between the apex of the frog and COR. In order to take this into account we looked at the relationship of the apex of the frog to COR using the length of the coronary band as an explanatory variable. This model predicted that in a hoof with a 90 mm coronary band length the COR would on average be placed 35.4 mm caudal to the apex of the frog in hind limbs and 34.1 mm caudal to the apex of the frog in front limbs. With a 130 mm coronary band the numbers would be 44.3 and 43.0 respectively. The standard deviation of this model was 4.34

mm and was slightly lower than the 4.94 mm of the model using the apex of the frog without taking the size of the hoof into account. Even though the difference in standard deviation was significant, a standard deviation of 4.34 mm with residual values up to 10.5 mm is still considerable. This may be due to measurement errors, anatomical variation or perhaps the fact, that some of the abattoir horses had received poor hoof care. It is also possible that the limbs not being loaded in a natural way may have contributed to a larger variation. Nevertheless, Craig (2015) found the relationship between the frog apex and the coffin bone to vary more than 12 mm in an average sized horse in a small study (n=31), confirming large inter-individual variation.

Live horse study

In the second part of the study we tested the model found to be most precise in the cadaveric study in 6 live horses in a loaded and an unloaded situation.
There was a very high correlation between the two test situations and no significant effect of loading. This confirms that dorso-palmar/plantar balance in an unloaded limb corresponds well to the dorso-palmar/plantar balance in a static loaded limb.
However the results showed that the used model systematically overestimated the distance from frog apex to COR with 6 mm on average. The reason for this overestimation is uncertain, but could be caused by hoof care neglect of the cadaver hooves and by the live horses having received regular hoof care, were trimming of the solar horn, could cause the estimation of the true apex of the frog to be placed more palmarly/plantarly than in the cadaver limbs. Another reason could be that the moisture content in cadaver limbs changes when the limbs are frozen and thawn, so that the relationship between coronary band and frog changes.

The standard deviations in the live horses were smaller than in the cadaver limbs. This might be a true difference, but could also be caused by the small number of live horses. Even though the standard deviations were relatively small the residual values when using the models were still up to 8 mm. This confirmed the large inter-individual variation found in the cadaveric study and in the study of Craig (2015).

Do these results mean that we have to stop using the methods that claim to identify the centre of rotation, centre of articulation or centre of the joint? The author still finds these methods useful, but it is important that farriers are aware of the limitations of these methods and that hoof care professionals are specific in their nomenclature, so that it is clear which (if any) internal structure the methods are used to identify.

Conclusions

Cadaveric study

None of the tested methods were precise in estimation of COR or COA, but all came closer to estimation of COA.

In this study the most accurate model for estimation of COR from external landmarks was based on the apex of the frog and the length of the coronary band.

The relationship between frog apex and COR could be described with the following models:
*Distance from frog apex to COR= 13.977+0.2235*length of coronary band (in mm)* in the front limb
*Distance from frog apex to COR= 15.2771+0.2235*length of coronary band (in mm)* in the hind limb.

Inter-individual anatomical variation was considerable.

When using this model, errors of up to 10.5 mm were found.

Live horse study

There was no significant difference in dorso-palmar/plantar balance between loaded and unloaded limbs.

The model for estimation of COR found in the cadaveric study systematically overestimated the distance from frog apex to COR with 6 mm on average.

There was a large effect of individual horses.

In live horses the relationship between frog apex and COR could be described with the following models:
Distance from frog apex to COR=-27.51 + 0.5539 length of coronary band (in mm)* in the front limb.
Distance from frog apex to COR=-8.97 + 0.3837* *length of coronary band (in mm)* in the hind limb.

Inter-individual anatomical variation was considerable.

When using this model, errors of up to 8 mm were found.

In order to precisely identify COR and/or COA of the coffin joint radiographic images are necessary.

Perspectives

Further studies are needed in a larger population of live horses of different type to confirm the findings in this study. Additional research regarding the correlation of the hoof size and the position of COR in relation to the apex of the frog could possibly establish a more accurate determination of the COR, but the author of this thesis suspects that the anatomical variation is too great to precisely estimate COR of the coffin joint from external reference points on the hoof capsule.
Substantial biomechanical research is being published in these years and hopefully some of it will contribute to the understanding of how the hoof should be trimmed and shod in order to maximize its mechanical efficiency and thereby prevent overload injuries, including how the hoof should be balanced around COR.

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