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Determining the radiological indices of the third phalanx in the forelimbs of ponies

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Abstract It is essential to monitor the condition and assess the functionality of motor organs in horses. The aim of this study was to use radiology to ascertain the biometric characteristics of the third phalanx in ponies, as there has been no comparison with other horse breeds and no detailed information regarding the size and angles of this structure has been obtained. In order to get lateral radiographs of the right and left front limbs, six clinically healthy mature ponies that were comparable in height, weight, and age were chosen. The lateral radiograph was used to measure the lengths, ratios, and changing morphometric angles of the third phalanx of the finger and hoof. Seven lengths, six angles, and a ratio between the knuckle's end and the hoof wall were measured and examined for every radiograph. The following dimensions were examined: width of the soft tissue in the hoof wall, palmar-cortical length (PCL) of the knuckle end, ratio of wall thickness to PCL, knuckle end axis, difference between S-angle and T-angle (H-angle), middle finger axis (U-angle), difference between U-angle and T-angle (R-angle), D-founder, S-founder and CF-founder, and P-angle. The results of this investigation showed that there is no statistically significant difference ($P<0.05$) between the radiography characteristics measured in the left and right hands of horses. Researchers, veterinarians, and pony breeders can utilize this information as a resource when examining illnesses of the third phalanx in ponies.

Introduction

A pony, or *Equus ferus caballus*, is a tiny horse. A pony could be a little horse with a particular body type and disposition, or it could refer to a horse that is smaller than the approximate or exact height at the saddle. Ponies tend to have thicker coats, manes, and tails than larger horses. They also often have shorter legs, wider hips, heavier bones, thicker necks, and shorter, broader heads. The old French word poulenet, which refers to a foal, young, immature horse, is where the name pony originates. Historically, ponies and tiny horses were employed as animals of burden, for carriage pulling, and for riding. Many served as mine ponies throughout the Industrial Revolution, particularly in Great Britain, where they hauled quantities of coal into the mines. They may be retained as kids' horses nowadays, for pleasure or competitive riding, or for cultural or environmental purposes [1].

A prominent trait of the hoof's moving body is its tough, sizable, and typically circular cross-section. Additionally, the metacarp/metatars in the front and rear locomotion organs has a proportionate and robust diameter, and the arms and legs are completely muscular. From bottom top, the pony finger is made up of the lower

phalanx, navicular bone, middle phalanx, and upper phalanx. Ponies, like other equines, have one motor toe with three phalanxes on each toe [2, 3, 4]. The first phalanx is jointed from the top with the metacarp/metatars bone and from the bottom to the second or middle phalanx. The hoof surrounds the finger's third joint. Additionally, the deep flexor tendon and the joint between the second and third finger bones are where you 1can find the lower sesamoid bone. The lower phalanx can be examined using radiographs, but ultrasonography can also be utilized. However, because the tissue covering this part of the finger has weak acoustic qualities, ultrasonography can be challenging in this area [5, 6].

While the accumulation of hoof sheets is referred to as laminitis, this word oversimplifies a complex and interconnected series of processes that result in varied degrees of hoof illness. According to the carried out research, a disorder known as fatty tissue edema is typified by a reduction in blood flow into the fatty tissue's capillaries. In this manner, the capillary network is bypassed by a direct blood flow path (arterial-venous shunt) from the artery to the vein, which results in discomfort and the death of the venom sheets [7, 8].. Recent studies have also demonstrated that poison ivy is really a localized symptom of a more extensive and general illness that can affect the kidneys, the blood coagulation mechanism, the circulatory and hormonal systems, and more [9]. Despite the fact that there are numerous recognized risk factors for the disease of the hoof's soft tissue, it appears that these risk variables share a common ultimate pathway that results in the illness. There are instances where the condition is so severe that the third phalanx rotates and may even penetrate the hoof floor [10, 11, 12].

In certain instances of bone-joint damage, radiography is also utilized to demonstrate the existence of bone injuries. Approximately half of horses with injured tendons or ligaments are lame when they see a vet. Increased heat and sensitivity, as well as swelling of the affected structure, are very frequently observed. Nerve block tests should be carried out if the tendon damage is absent from the area and there is lameness, fever, or discomfort. If the radiographs do not show anything special, ultrasound can be used [13, 14, 15, 16].

Navicular syndrome, amass of the third phalanx, subcartilaginous bone cysts of the third phalanx, fractures of the third phalanx, fractures of extensor process of the third phalanx, coitus (bilateral cartilage necrosis), side bones, disease Pyramid, buttress hoof, penetrating wounds in the hoof area, white line or gravel penetrating wounds, white line disease, corns and contusion of the hoof floor, hoof rot, hoof frog disease, separation of the hoof wall in the heel area, and cracks in the claw, walls, and heel are among the other conditions affecting the third phalanx of the pony’s toe [17, 18, 19, 20, 21].

The purpose of this study was to assess the radiological markers of the anterior limb of the third phalanx in ponies, taking into account the many diseases and difficulties associated with the horse's third phalanx.

Materials and Methods

Animals

Six female ponies were chosen from veterinary faculty of Shahid Bahonar University of Kerman, with an average age of 4 + 7 years. Each pony had a birth certificate, a pedigree, and was about the same size and weight. The animals were under the care of a veterinarian, who also oversaw their diet, activity, and reproduction. Prior to investigations in ponies, there was no history of lameness or motor impairment for a minimum of one year.

Method

A portable X-ray machine was employed in this study. In addition, in lateral-medial radiographs, a metal marker was utilized to identify the coronal band and radiographic magnification. The poison was applied to the specified polished brick, which had a thickness of 5 cm, for radiography. In order to capture a radiograph, we positioned the radiograph device in front of the target organ at a consistent distance of 80 cm and the digital film cassette behind the organ. Upon printing, the required inspections were carried out using the

negatoscope. To get accurate distances, all radiographic computations in the mid-lateral view were multiplied by magnification correction factors (MCF). The metal marker's real length was divided by the marker image's length on the radiograph to determine the MCF. With every radiograph that was acquired; Six angles and seven distances were measured, and morphometric analysis was performed. The thickness of the soft tissue in the hoof wall is divided into three regions: The entire thickness of the soft tissue in the third phalanx, extending from the dorsal (cranial) profile to the lower portion of the phalanx (Total soft tissue Thickness dorsal to the distal aspect of the DP or STTD). B: The third phalanx's entire thickness of soft tissue, extending dorsally (cranial) to the middle of the phalanx (Total soft tissue Thickness dorsal to the Middle aspect of the DP or STTM). C: The entire thickness of the third phalanx's soft tissue, extending dorsally (cranially) to the top region of the vertebra (Total soft tissue Thickness dorsal to the Proximal aspect of the DP or STTP).

Statistical analysis

Ultimately, SPSS (Ver. 11.5) software was used to analyze all of the data collected, and the data's mean and standard deviation were found; Furthermore, the variables of the right and left hands were compared using the paired T-test at a significant level ($p<0.05$).

Results

The measurements of the lengths, ratios, and changing morphometric angles of the hoof and phalanx ends in the lateral radiograph of each of the pony's left and right forelimbs are displayed in Tables 1 and 2. There was no discernible variation between the left and right foot radiographic data measured, according to the statistical analysis ($p<0.05$).

Table 1. Measured mean + standard deviation of the lengths and ratios of morphometric variables of the foot and third phalanx in horses' left and right forelimbs on lateral radiographs.

Variables	*The overall mean (standard deviation)*	*Left hand mean (standard deviation)*	*Right hand mean (standard deviation)*
STTD (mm)	8.30 (± 0.7)	8.35(± 0.46)	8.25(± 0.98)
STTM (mm)	11.19(± 0.87)	11.15(± 0.96)	11.23(± 0.78)
STTP (mm)	9.48(± 0.58)	9.51(± 0.39)	9.45(± 0.77)
PCL (mm)	35.15(± 1.24)	35.18(± 0.8)	35.11(± 1.68)
STTD/PCL (%)	23.51(± 0.64)	23.65(± 0.82)	23.38(± 0.46)
STTM/PCL (%)	31.73(± 0.69)	31.58(± 0.51)	31.88(± 0.87)
STTP/PCL (%)	26.86(± 0.94)	26.93(± 0.66)	26.8(± 1.22)
D-Founder (mm)	6.20(± 0.51)	6.25(± 0.77)	6.16(± 0.25)
S-Founder (mm)	8.21(± 0.73)	8.2(± 0.91)	8.23(± 0.53)
CF-Founder (mm)	28.11(± 1.13)	28.23(± 0.43)	28(± 1.83)

Table 2. The average standard deviation of the third ligament and hoof assessed angles and morphometric variables in the ponies' left and right forelimb lateral radiographs.

Variables	*The overall mean (standard deviation)*	*Left hand mean (standard deviation)*	*Right hand mean (standard deviation)*
S-angle (degree)	51.67(± 1.56)	51.46(± 1.78)	51.88(± 1.34)
T-angle (degree)	59.08(± 1.43)	59.23(± 1.62)	58.93(± 1.24)
H-angle (degree)	7.4(± 1.02)	7.76(± 1.17)	7.05(± 0.87)
U-angle (degree)	65.72(± 1.19)	65.73(± 0.98)	65.71(± 1.4)
R-angle (degree)	6.46(± 1.25)	6.5(± 1.73)	6.43(± 0.77)
P-angle (degree)	27.41(± 0.89)	27.48(± 1.03)	27.35(± 0.75)

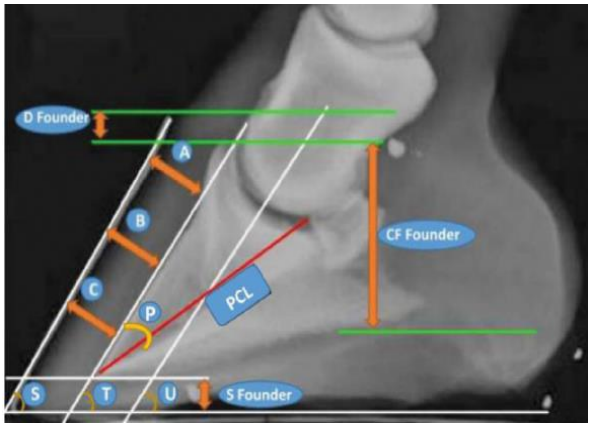

Fig 1. A: Full-thickness soft tissue in the third phalanx with a dorsal-cranial profile to the upper part of the third phalanx. B: full thickness soft tissue in the third phalanx - anterior to the middle part of the third phalanx. C: Full thickness soft tissue in the third phalanx with dorsal-cranial profile to the end of the third phalanx. D-Founder: The vertical distance between an imaginary horizontal line along the extensor process and an imaginary horizontal line along the coronary band. CF-Founder: the vertical distance between an imaginary horizontal line at the highest point of the palmar surface of the third phalanx, which is stained with a high-contrast substance such as barium sulfate, and is located in front of the frog to the tip of the third phalanx. S-founder: The perpendicular distance from the horizontal line through the highest point of the sole surface p-angle: The dorsal angle formed between the imaginary line drawn from Palmarocortical and the imaginary line drawn on the dorsal surface of the third phalanx. S-angle: dorsal angle formed between an imaginary straight line on the anterior surface of the hoof wall and an imaginary straight line on the weighting surface of the hoof. T-angle: the dorsal angle formed between a hypothetical straight line on the front surface of the third phalanx and a hypothetical straight line on the weighing surface of the hoof wall. U-angle: back angle formed between an imaginary straight lin e that passes through the middle phalanx and an imaginary line that is drawn on the weighting surface of the hoof wall. PCL: palmarocortical length below the third phalanx

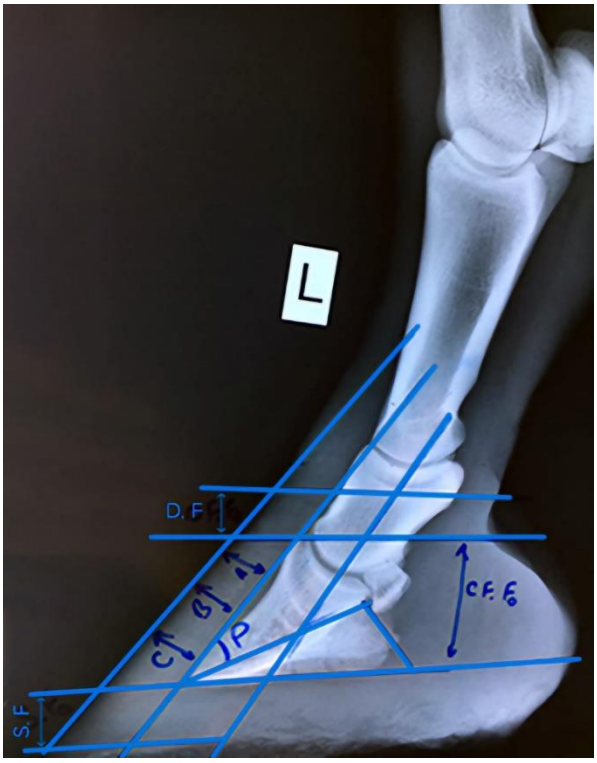

Fig 2. Lateral-medial radiograph of pony No.1

Fig 3. Lateral-medial radiograph of pony No.2

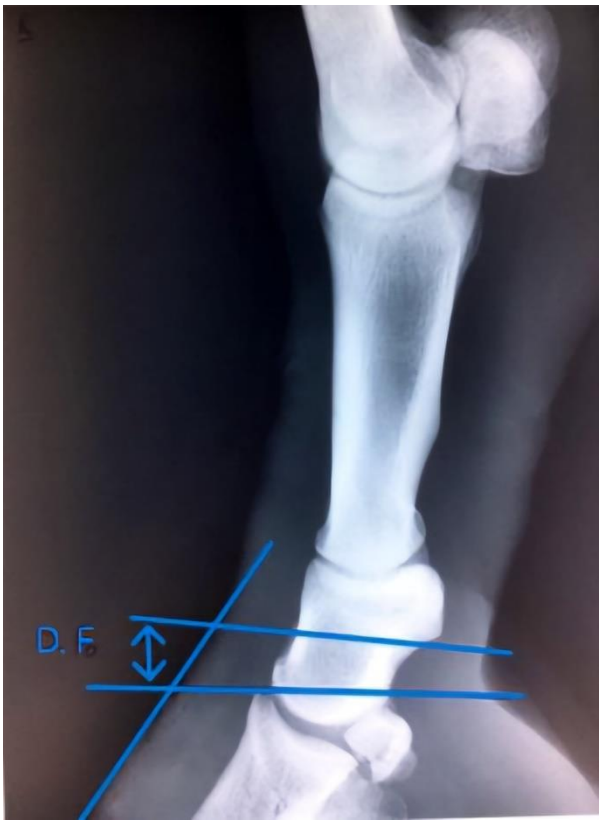

Fig 4 Lateral-medial radiograph of pony No.3

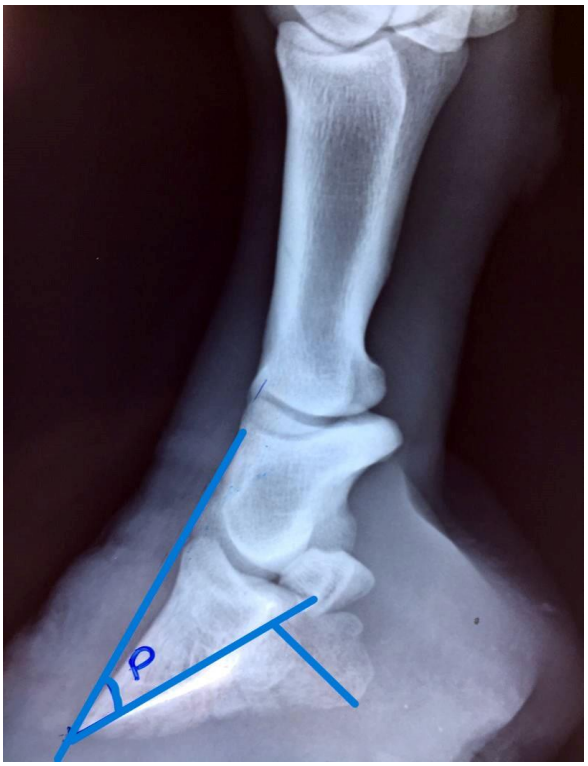

Fig 5. Lateral-medial radiograph of pony no.6

Discussion

Pony is very valuable in terms of beauty and genetics. Therefore, it is very important to pay attention to the health and evaluate the performance of the animal's limbs. One of the common diseases in these horses is diseases of the limbs. Diagnostic imaging may be used to comprehensively analyze movement organ issues, such as irritation and bone fractures, joint illnesses, and issues with the toes and hooves, which are frequent in horses. Once a diagnosis has been made, an appropriate treatment plan should be implemented. The understanding of diagnostic imaging, such as radiography, and the progress of veterinary research have made it possible to evaluate issues with the horse's motor organs more efficiently and precisely these days [22]. In order to show how accurate this approach is, the current study assessed the radiological markers of the anterior limb of the third phalanx in ponies. Motor organ illnesses can be diagnosed with the help of quantitative radiographic indications that measure the degree of involvement in the hoof trim. The radiography

technique for laminitis showed a fair degree of diagnostic accuracy in the study horses. In a research published by soroori et al. 2023 assessed the radiographic quantitative markers that were useful in identifying laminitis in horses in good condition both before and after hoof rectification and stated that the D-founder index of the right and left anterior limbs before and after the hoof trim was modified did not show any statistically significant differences [23]. However, the other four indicators examined—the thickness between the dorsal surface of the third phalanx and the dorsal surface of the hoof, the angle between the back surface of the third joint and the back surface of the hoof, the thickness of the hoof's sole, and the ratio between the thickness of the third joint's back surface and the longest length of the finger in each organ before and after hoof modification—showed a statistically significant difference [23]. Cripps et al. (1999) assessed each horse's height from the withers to the ground as well as the length and width of each hoof while taking lateral radiographs of 25 healthy horses. The D-founder index received particular attention in this study because of its significance in the diagnosis of laminitis. There was a notable variation in D-founder and hoof wall thickness across the various breeds. Over the course of the study's six weeks, there was no discernible change in the quantity of D-founder. Furthermore, it was stated that the angularity inaccuracies in X-rays had little clinical importance [24].

Diseases that cause significant financial and economic losses to animal owners, such as laminitis, navicular syndrome, amass of the third phalanx, subcartilaginous bone cysts of the third phalanx, fractures of the third phalanx, quittor and side bones, are of the greatest significance. The structures known as laminae are what attach the third bone to the interior of the hoof wall. These injured or irritated laminae can be quite painful. Lameness may be followed by the third phalanx, which may twist or, in more extreme situations, sink into the hoof [26, 27].

Lameness in both forelimbs is common, which makes sense given that this limb carries 60% of the weight of a single hoof. However, lameness in the hind limb can occasionally be seen. A notable rise in the angle of deviation between the posterior surface of the third phalanx and the rear of the hoof wall, as well as finger rotation and an increase in the displacement of the third phalanx's end, are the anatomical changes that result in lameness [27, 28]. Radiological examining of hoofs is one of the most crucial steps in verifying the diagnosis of laminitis and navicular disease. An X-ray examination of the foot is used to detect variations in the animal's hoof level and third phalanx of the toe, which may indicate that the animal is unable to move [24]. The gold standard view for diagnosis and assessment is the lateral-medial radiographic view. As soon as acute lameness appears, a lateral-medial radiograph has to be done. A little bony response along the third phalanx's dorsal surface and an increase in the distance between the phalanx and the hoof's rear wall are two of the early radiographic indicators of lameness. In a healthy pony, the gap between the tip of the bone and its junction with the navicular bone should be less than 21 mm, or less than 30% of the length of the third bone. Lameness is identified by the rotation of the hand or foot's third phalanx's sole with respect to its angle with the hoof's rear wall [24]. The morphometric features of the limb's third phalanx are defined by these investigations, and they may be utilized in both situations to assess the third phalanx's anatomy and the alterations that result in third phalanx injury. To properly assess the kind and amount of structural alterations in the afflicted limb, a variety of radiological criteria need knowledge of the whole anatomy of the lower limb. Merely depending on measurements is insufficient. Additionally, the ability to precisely identify a very slight change in the afflicted organ is crucial from a therapeutic perspective [13]. For example, in the study conducted, measuring the angle of the dorsal surface of the third phalanx and the ground line has provided an improvement in the previous methods of evaluating the third phalanx. Other parameters that can increase the accuracy of diagnosis and inherent errors related to the measurement of radiological parameters should also be taken into consideration. The angles caused by DPH in a typical horse range from 2° to 10° [20]. These angles are different in

the long toe/short heel structure because the hoof's horn section is extended due to the third phalanx's angle being closer to the ground than the leading edge. The tensile tension of the DDFT and, consequently, the force applied to the navicular bone may both rise as a result of this change in angles caused by the DPH's orientation. Numerous research articles have been published about the measuring of the forelimb's hoof [29]. Several horses' forelimb angles were measured by Cripps and Ostas [24]. The average angle of S and T in the anterior limbs of twenty-two purebred horses was discovered to be 48.6 degrees and 47.6 degrees, respectively. These parameters' measures in our study were 51.67 and 59.08, respectively, and they differed significantly from one another. The H angle recorded in our study is 4.7, but Collins et al.'s study (2011) found that it was 5. According to Collins et al. (2011), the R angle was 4.3 degrees, while the U angle was 57.6 degrees. Our research's conclusions differ somewhat from theirs. These parameters' measures in our study were 51.67 and 59.08, respectively, and they differed significantly from one another. The U and R angles in our study were 72.65 and 46.6, respectively. A research by Collins et al. (2011) found that in typical ponies, the ratio of hoof wall thickness to PCL is less than 35%. In the upper, middle, and end sections, our scores were (0.64) 51.23, (0.69) 73.31, and (0.94) 26.86, respectively. This shows that this measure's average is lower than 35% in every instance, despite the fact that typical horses have hoof walls that are less than 30% thick to PCL, according to Linford et al. (1993) [29] . Differences in the size of the hoof wall's thickness and its soft tissue were observed in the current study in comparison to studies by Peloso (1996), Cripps (1999), and Linford (1993) [24, 29, 30]. Additionally, the type of hoof trim, the quantity of sports activities the animal engaged in, and feeding practices were observed in the tested ponies.

D-Founder's measurement, defined as a vertical line from the extensor process to the coronal band, can be used as a diagnostic feature in Laminitis justification considered, since determining the position of the coronal band is typically very difficult in cases of hoof inflammation (laminitis). Features like CF-Founder and S-Founder were added with considerably greater accuracy as a replacement for D-Founder in situations of hoof inflammation in Masoudifard et al.'s (2014) study [31]. Additionally, we believe that CF-Founder and S-Founder are more specific than D-Founder when it comes to hoof inflammation. This is because D-Founder imaging may not accurately detect the coronal band, especially in ponies, making it difficult to recognize. Characteristics like CF-Founder, S-Founder, and D-Founder were employed in the current study endeavor. In our study, the average vertical distance in the right and left hands of ponies is 7.45 mm and 7.55 mm, respectively, between a hypothetical line measuring the length of the opening appendage and a hypothetical horizontal line measuring the length of the opening appendage (D-Founder). The total average of these measurements is 7.51 mm. Compared to previous studies, these figures are greater. The length of the hoof walls and species differences may be the reason of this variation. Following a statistical analysis of the collected data, it was discovered that the assessment of the previously indicated radiographic parameters in the left and right hands of ponies did not differ significantly in the current study. The goal and findings of this study point to the need for more research on the incidence and management of various illnesses affecting the third phalanx in ponies in order to better understand the prevalent conditions affecting this breed and identify the most effective treatments.

Conclusion:

The results of this investigation showed that there is no statistically significant difference ($p<0.05$) between the radiography characteristics measured in the left and right hands of horses.

Acknowledgements

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Conflict of interest

The authors declare that they have no competing interests.

Ethical approval

All ethical considerations including utilizing animals were considered cautiously. In addition, the trial convention was affirmed by the animal welfare committee of the Faculty of Veterinary Medicine, Shahid Bahonar University of Kerman, Kerman, Iran. All applicable international, national, and/or institutional guidelines for the care ssand use of animals were followed.

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