QUANTITATIVE COMPARISON
OF THE PARAMETERS OF THE SPONGIOUS SUBSTANCE
OF THE BILATERAL PROXIMAL PHALANX
OF THOROUGHBRED HORSES

MAŁGORZATA DZIERZECKA, ANNA CHARUTA¹,
EDWARD CZERWIŃSKI², AND TOMASZ MAJCHRZAK³

Department of Morphological Science, Faculty of Veterinary Medicine,
Warsaw University of Life Sciences, 02–776 Warszawa, Poland
¹Department of Vertebrates Morphology, Faculty of Agriculture,
University of Podlasie, 08-110 Siedlce, Poland
²Department of Bone and Joint Diseases, Collegium Medicum,
Jagiellonian University, 31-501 Krakow, Poland
³Faculty of Mechanical Engineering and Robotics,
AGH University of Science and Technology, 30-059 Krakow, Poland
malgorzatadzierzecka@wp.pl

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Abstract

The proximal phalanges, especially those of the thoracic limbs of horses, are the ones most exposed to injuries in the species. Due to unequal loading of the lateral pastern bones resulting from the specific training of racehorses in Poland and from the way races are conducted, the authors of the publication aimed at a detailed quantitative profile based on a radiogram analysis of the lateral proximal phalanges of the thoracic limbs of such horses. It seemed to be interesting also due to the fact that there is hardly any information in literature concerning asymmetry between the lateral long bones in the species. It turned out that the differences concerning the structure of the spongious substance between the bilateral pastern bones in the studied group of horses are not statistically significant. It was also stated that there is a strong positive correlation between the parameters mentioned above as far as the proximal phalanx of the right thoracic limb and the left one were concerned.

Key words: racing horses, proximal phalanx, radiograms, computer analysis.

Limb diseases are the most frequent pathology observed in the species. They are the reason for interrupting or even ending the sporting careers for some individuals (12, 15, 19). Based on the previous four years of research conducted on 850 Thoroughbred horses, which took part in race training, it can be stated that diseases involving the locomotor system occurred in 60.4% of the animals, among which bone diseases resulting from injuries were the most frequent. The research showed that fractures constituted 30% of all injuries, and the proximal phalange fractures were the most frequent (39.6% of all fractures). They are mostly oblong fractures, rhabdoidal (12). Other data show that fractures of the pastern bones of the thoracic limbs are the most frequent injuries (13, 19, 23).

According to previous research, the overall percentage of the recorded cases of fractures of the thoracic limbs is bigger than the percentage of fractures of the pelvic limbs, and amounts to 85.1% and 14.9% respectively (12). Differences in the frequency of injuries of the thoracic and pelvic limbs can be explained by the fact that the thoracic limbs are more loaded in comparison with the pelvic ones, which results from the location of the centre of gravity of a horse’s body. The increased loading of the thoracic limbs of racehorses results from a specific backing of a horse by a rider, in which the rider’s body weight is moved to the front in order to prolong the horse’s action while galloping (8, 18).

Due to the above, the analysis of the structures of the trabeculae, which play a very significant role in creating the resistance of the bone tissue, which is most exposed to injuries, the proximal phalanges of the thoracic limbs seemed to be the most needed and justified. Authors of the publication aimed at a detailed quantitative profile based on a radiogram analysis of the lateral pastern bones of the thoracic limbs of such horses. Along with the intravital evaluation of the bone system, through such as radiography, dual energy X-ray absorptiometry, a digital fluoroscopy, quantitative
computed tomography appeared to be one of the few possible intravital ones in horses (10, 11).

Quantitative comparison of the parameters of the spongious substance of the lateral proximal phalanx seemed to be particularly interesting, also due to the fact that there is hardly any information in literature concerning the asymmetry between the lateral long bones in the species. The only available publication concerns the asymmetry between the lateral metacarpal bones III and the femoral bones (9, 20). Moreover, it appeared to be very interesting because of the specific form of training and the way the races are conducted on racetracks in Warsaw during which the left thoracic limb is loaded more intensively.

Służewiec Racetrack in Warsaw is both the place for horse races and the place where two breeds of horses (Thoroughbred horses and Arabian horses) are trained. Both the training track and the racing track are oval-like where two long opposite straight lines are parallel to each other. The training track is built of three tracks, two of which, smaller ones, are located inside the third one which has an 1,800 m perimeter. The training tracks have a sandy surface with some clay in it. The racing track has a grass surface and is 2,300 m long. Training sessions on the sandy track take place six days a week - every other day on the right side and the three other days on the left side. As far as the loading of the locomotor system is concerned, it is significant that on days when the training is conducted on the right side, horses usually gallop a slow pace covering a small distance. On the other three days when horses go to the left side, Training sessions are usually more intensive, taking into account both the distance and the pace. It is also important that during extremely hard work, race horses also gallop to the left. All attempts to check if horses are well prepared for races, are also conducted leftside (private information).

While galloping on the arch to the left side the body weight is moved to the left side. The first limb, which goes forward during the race left, is the left thoracic limb, otherwise called the leading limb. It is also the limb, which takes the whole body weight during one of the stages of the racing gallop (over 60 km/h).

**Material and Methods**

The research material consisted of radiograms of the proximal phalanx of the right and left thoracic limbs of ten Thoroughbred horses - the breed for which the most basic selective criterion is their racing activity. The age of the horses ranged from 2 to 7 years. Due to the fact that the results of previous radiogram analyses of the proximal phalanx using a Trabecula programme showed that the values of the parameters are similar for both sexes and the differences between them were not significant (11), the examined horse population was treated homogeneously.

The animals stayed at Warsaw Racetrack where they were trained in an intensive way and trial races were conducted (flat races). The examined horses did not show any signs of lameness or other clinical symptoms indicating diseases of the locomotor system. The animals were of both sexes.

The radiograms were made at Służewiec Hospital for Horses in Warsaw and were taken with the use of a portable Gierth apparatus. The central beam going through the centre of the length of the shaft of the proximal phalanx was attempted. The limb location and the conditions for taking photos were the same every time: dorso-palmar projection (A-P), the distance between the object and the lamp 90 cm, exposition conditions 65 kV, exposition time 0.16 s. Radiological AGFA films measuring 18x24 cm were used. Developing of the photos was conducted in the same conditions.

The examination of the structure of the bone tissue was based on computer image analysis using the Trabecula programme (3-7). It was based on the digital record of a radiological image in the form of a bitmap made using CCD. The study of the structure of the bone tissue was preceded by the method adaptation (11). The fragments chosen for the analysis of the structure of the spongious substance of the proximal phalanx were rectangular-shaped, taken from the central part of the shaft, below the joint surface near the proximal end of the bone called in clinical language the proximal metaphysis (Fig. 1).

The place of the measurement was intentional – the central part of the proximal metaphysic of the proximal phalanx. It is the place in which the marrow cavity of

![Fig. 1. Fragment of the original radiogram of the pastern bone with a marked area of analysis.](image)
the bone is the biggest, and so is the quantity of the spongious substance. Due to the fact that Trabecula programme is based on computer-image analysis of the bone spongious substance, the selected place of the measurements referred only to the substance, not to the cortical bone. It is also the place where fractures of the proximal phalanges occur most frequently.

The applied programme, according to its definition, recognised the trabecula as a segment of a densitometer curve in a quadrilateral shape with an ascending stage, a plateau and a descending stage. Algorithm parameters in the form of critical angles of the ascending and descending arms for the proximal phalanges had been determined earlier, applying experimental variables (angles: 20°, 30°, 40° and levels 20%, 40%, 60%). To establish which of the parameters are optimal while analysing the structure of the proximal phalanges, a number of trabeculae in given horizontal lines on the marked surface of the radiogram were determined with the naked eye. Then the number was compared with the results achieved using Trabecula programme, which depended on the selection of individual parameters (11).

A 128 x 128 matrix was used in the analysis. Having established the optimal parameters of the analysis, trabeculae were recognised when the angle of rising stage and the angle of falling stage were 20°. According to this algorithm the programme analysed 128 densitometer curves and made a map of recognised trabeculae, then it calculated their characteristics for the whole surface as an average from the analysis of the given 128 horizontal lines on the marked area (Fig. 2).

The programme generated the trabeculae map and for the whole area of the analysis it calculated the number of recognised radiological trabeculae per mm² of the marked analysis area; the average volume of the trabeculae as a percentage of the volume of a cube with the maximum and minimum basis measured given in % mm; and density given as a percentage of the surface covered with trabeculae.

To establish the differences between the studied quantitative traits, which could be connected with the left or right side of the proximal phalanx, the achieved results were analysed separately for the left -LP and the right -RP proximal phalanx.

The achieved results on the spongious substance of the proximal phalanx were analysed statistically. Descriptive statistics were determined: the average and coefficient of variability parameters. The normality of the studied parameters was checked using the Shapiro-Wilk test. Average values of the parameters were compared using Student t-test for matched pairs. Pearson’s correlation coefficients between the results achieved from the right and left proximal phalanx were calculated and their significance was examined. All statistical calculations were made using Statgraphics, a statistical programme.

![Fig. 2](image). Computer analysis of the radiological image of the spongious substance of the proximal phalanx. Left side: at the top – parameters of radiological tabeculae calculated by the programme for the whole marked area; bottom left– 3D image of the bone structure in the form of diagrams with microdensitometer curves; top right – a map of discovered radiological trabeculae on the marked area, bottom right - a fragment of the original radiogram generated by a computer, at the bottom – an image of detected radiological trabeculae on one of the microdensitometer curves.
Table 1
Parameters of the trabecula structure of the spongious substance of the proximal phalanx and their statistical estimation for the right thoracic limb (PP) and the left thoracic limb (LP) of the 10 examined horses, respectively

<table>
<thead>
<tr>
<th>Statistical parameters</th>
<th>PP (n=10)</th>
<th>LP (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of radiological trabeculae per mm²</td>
<td>7.90–11.29</td>
<td>9.26–11.09</td>
</tr>
<tr>
<td>Volume of trabeculae %mm²</td>
<td>0.59–1.39</td>
<td>0.64-1.56</td>
</tr>
<tr>
<td>Density of radiological trabeculae</td>
<td>36.26–47.23</td>
<td>40.08-48.65</td>
</tr>
<tr>
<td>min. – max. value</td>
<td>10.44%</td>
<td>28.38%</td>
</tr>
<tr>
<td>Average</td>
<td>9.88</td>
<td>1.04</td>
</tr>
<tr>
<td>Variability coefficient V%</td>
<td>10.44%</td>
<td>6.00%</td>
</tr>
</tbody>
</table>

Table 2
Pearson’s correlation coefficient and the results of the matched-pairs test between the parameters of the trabecula structure of the spongious substance of the proximal phalanx for the right thoracic limb, and left thoracic limb of the 10 examined horses, respectively

<table>
<thead>
<tr>
<th>Pearson’s correlation coefficient (n=10)</th>
<th>Matched pairs test (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of radiological trabeculae per mm²</td>
<td>Value of the empirical statistics</td>
</tr>
<tr>
<td>Volume of trabeculae %mm²</td>
<td>0.94</td>
</tr>
<tr>
<td>Density of radiological trabeculae</td>
<td>0.85</td>
</tr>
<tr>
<td>Number of radiological trabeculae per mm²</td>
<td>1.42</td>
</tr>
<tr>
<td>Volume of trabeculae %mm²</td>
<td>0.002</td>
</tr>
<tr>
<td>Density of the radiological trabeculae</td>
<td>0.002</td>
</tr>
<tr>
<td>Probability p</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Probability p</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Results
On the basis of the computer radiological image analysis using Trabecula programme, a quantitative examination of the structure of the spongious substance of the proximal phalanges was made (Table 1). It appeared that the differences between the lateral pastern bones in the group of 10 horses were not statistically significant as far as the following parameters were concerned (Table 2): the number of recognised radiological trabeculae per mm² of the marked analysis area and density given as a percentage of the surface covered with trabeculae. Significant statistical differences between the right and the left proximal phalanges occurred with reference to the average volume of the trabeculae; however, the parameter was characterised by the greatest variability correlation (Table 1), and as a result by a normal standard error. Based on the analysis of correlation of the examined parameters of the structure of the spongious substance of the proximal phalanges, a strong positive correlation between the studied parameters of the right thoracic limb (PP) and left thoracic limb (LP) was noticed – Table 2. Therefore the results achieved from only one of the limbs (left or right) reflect the properties of the other proximal phalanx.

Discussion
One of the programmes concerning determining parameters of the bone structure on a radiogram, resistance of the bone tissue, is the Trabecula programme, which allows us to examine the architectural system of trabeculae (it plays a very significant role in forming the resistance of the bone tissue). The method has been widely used in diagnostics of fluoric and osteoporotic changes in humans (1, 3-7, 14, 16, 17, 21, 22), as well as in veterinary medicine to examine the structure of the tibiotarsal bones in ostriches (2). The conducted research showed that Trabecula programme used on humans and to examine the trabecula structure of the spongious substance of the tibiotarsal bones in ostriches can be also adapted to be used on horses (10, 11).

On the basis of the computer radiological image analysis using this programme, a quantitative examination of the structure of the spongious substance of the proximal phalanges of Thoroughbred horses was made. It appeared that the differences between lateral proximal phalax in the group of 10 horses were not statistically significant as far as the following parameters were concerned: the number of recognised radiological trabeculae per mm² of the marked analysis area and density given as a percentage of the surface covered
with trabeculae. Significant statistical differences between the right and the left pastern bones occurred with reference to the average volume of trabeculae.

Values of parameters of trabecula structure of the pastern bones of the LP and PP are presented in Table 1. The number of trabeculae was bigger in LP and amounted – 10.19/mm², whereas in PP it was 9.90/mm². As far as density was concerned, it was bigger in left limbs – about 44.33% of the surface, while right limbs had density of 43.28%. However, the difference between the lateral proximal phalanges of the thoracic limb concerning these parameters was not statistically significant.

The previous research conducted on humans showed important statistical relationships between the histomorphometric parameters of the trabecula bone such as density of the osteoid and the number of trabeculae detected based on radiogram analysis. At the same time, the results of the radiogram test analysis with the use of the Trabecula programme on humans proved that the smallest measurement error is characteristic for density (6.6%) the biggest error appears for volume (17%). The error for measuring the number of radiological trabeculae was 12.2% (5). Therefore, it can be assumed that according to the most credible parameters of the structure of the spongious substance of bones on radiograms such as the number of radiological trabeculae per mm² and density of the radiological trabeculae, there are no differences between the bilateral proximal phalanges of the thoracic limbs of horses. When differences are not statistically significant, it means that they are random. On the basis of the conducted analysis, it can be claimed that despite the track fencing and bigger loading of the left thoracic limb connected with racing, Thoroughbred horses do not show any differences concerning the spongious substance of the lateral proximal phalanx of the thoracic limbs to the advantage of the left limb.

One of the few papers concerning the asymmetry of the structure of horses’ limb bones is on the femoral bones of racehorses (20). The analysis of 11 individuals was conducted post mortem; however, the animals were latent due to reasons other than lameness of the pelvic limbs. Having isolated and made 37 measurements of each of the lateral femoral bones, it turned out that the differences between the lateral femoral bones in reference to the five measurements made were statistically significant and bigger in the left femoral bones. In this case, the differences between the lateral femoral bones were explained by the track fencing and what is connected with it – a bigger loading of the left side of racehorses (20). The lack of significant differences concerning parameters of the spongious substance of the lateral proximal phalanges of the thoracic limbs is thus very interesting. The research concerning the asymmetry between the bilateral long bones was conducted in Thoroughbred racehorses in Australia and referred to the third metacarpal bone. The animals were of a similar age and were exposed to similar trainings. The research showed that in individuals, whose bilateral third metacarpal bones differed significantly as far as length was concerned. There was also a significant difference in the thickness of the cortical bone on the dorsal side. Comparing the lengths of the bilateral third metacarpal bones, it was stated that the differences were not statistically significant (9).

Another very important observation on the basis of the conducted research was that there is a strong positive correlation between the studied parameters for the proximal phalanges of the PP and LP. Having the results concerning parameters of the spongious substance of one of the proximal phalanges (left or right), we can describe the properties of the proximal phalanges of the other limb.

The results of the digital analysis of the radiological image concerning the lateral proximal phalanges of Thoroughbred horses obtained in the study are extremely interesting and encourage continuation. There are plans to conduct similar analysis on a bigger number of individuals in the future.

References