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# Craniometric values of the domestic horse (*Equus caballus*) in the context of mechanical stunning anatomy – preliminary studies

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## Abstract

This study presents selected craniometric measurements compared to the thickness of the frontal bone of the domestic horse. The study was carried out on 10 domestic horse skulls from the collection of the Institute of Veterinary Medicine at Nicolaus Copernicus University in Torun. On the basis of the results obtained, correlation was carried out according to Pearson's method, and a trend graph was created, showing the relationship of individual values to frontal bone thickness. The present research is a preliminary study, and further research, based on a larger study group, can help minimize their suffering. According to the study, the greatest positive correlation and relationship is shown by the length between the alveolar borders of the third incisor, while a negative correlation was found for the width of the cerebrocranium. In the future, it is possible to develop a formula to estimate the thickness of the frontal bone in horses.

**Running title:** Craniometry of domestic horse

**Keywords:** animal anatomy, craniometry, skull, domestic horse

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## Introduction

The food system contributes significantly to global greenhouse gas emissions. All stages of the supply chain contribute, but on average, the agricultural stage is the largest emitter of greenhouse gases, and animal products are the most carbon-intensive types of food [1]. Thus, it is known that animal husbandry significantly contributes to global greenhouse gas emissions and climate change [2,3]. The undeniable link between animal agriculture and climate change underscores the urgent need to reconsider our food choices. Despite growing awareness of these issues, global meat consumption continues to rise, fueled by population growth. This growing demand not only exacerbates environmental damage, but also raises serious ethical questions. The practice of raising and slaughtering animals, especially in industrialized systems, involves significant animal suffering. Practices such as stunning animals before slaughter are becoming central to discussions of the slaughter process, particularly in the context of minimizing suffering, making a thorough understanding of these methods crucial to assessing their impact on animal welfare.

Stunning horses are most often accomplished by ejecting a bolt due to the force of ejection from a blind bullet from a "radical" type slaughter apparatus. A skilled slaughterer applies the tool to the area of the frontal bone (*os frontale*) of the horse and the result is severe and irreversible damage to the brain (*cerebrum*) due to shock and penetration by the said projectile [4]. Correctly, the device should be applied at right angles to the surface of the bone at a point above the intersection of the lines running from the outer angle of the eye (*angulus oculi lateralis*) to the opposite base of the auricula (*concha auriculae*) [5].

The frontal bone is a paired bone located between the nasal and parietal bones. It consists of three main parts: the nasal part (*pars nasalis*), the frontal squama (*squama frontalis*), and the orbital part (*pars orbitalis*). In anatomical description, there are also distinct borders named after the adjacent structures, including the orbital margin (margo orbitalis), nasal margin (*margo nasalis*), parietal margin (*margo parietalis*), and sagittal margin (*margo sagittalis*). A notable anatomical feature in horses is that, unlike in other animal species, the entire frontal bone is pneumatised by the frontal sinus (*sinus frontalis*) as a single undivided chamber. This sinus is connected to the dorsal conchal sinus (*sinus conchae dorsalis*), forming the so-called conchofrontal sinus (*sinus conchofrontalis*). The posterior boundary of the sinus is defined by a line connecting the posterior edges of the zygomatic processes (*processus zygomaticus ossis frontalis*), while the anterior boundary is a line connecting the halves of the facial crests (*crista facialis*) [6-8].

This study aims to conduct a craniometric analysis of the horse's skull, with particular emphasis on the mechanisms of mechanical stunning with a bolt slaughter apparatus. The results obtained may find practical application, allowing pre-slaughter measurements to be made on the basis of bony structures available by palpation. This may make it possible, in the future, to estimate the individual distance a slaughter apparatus cartridge must travel to reach the central nervous system. This research is particularly important in the context of improving animal welfare by ensuring that animals are stunned more precisely, thus minimizing animal suffering during the slaughter process. In the future, these results may contribute to the development of guidelines or tools that will increase the accuracy and effectiveness of stunning methods.

## Materials and methods

The methodology of the study involved performing craniometric measurements on 10 domestic horse skulls from the collection of the Institute of Veterinary Medicine at Nicolaus Copernicus University in Toruń. The material was entirely obtained post-mortem, so ethical committee approval was not required. The selection of measurements was made with the potential for future in vivo measurements at the slaughterhouse in mind, and the types of measurements were inspired by the publication by Komosa et al. [9]. Each measurement was taken using a flexible zootechnical tape measure with an accuracy of 0.1 cm, or, for smaller distances, with a caliper with an accuracy of 0.01 mm. Measurements were carried out by one person. The measurements taken with the caliper included: the thickness of the frontal bone, the width of the orbit (*orbita)*, the height of the orbit, the length of the diastema, the distance between the supraorbital foramina (*foramen supraorbitale*), and the length between the alveolar boundaries of the third incisor (*incisor*). The remaining measurements, taken with the tape measure, included: the maximum width of the skull, the maximum height of the skull, the maximum length of the skull, the maximum width of the face (*facies*), the width of the forehead (*frons*) measured between the zygomatic processes, the distance between the maxillary tuberosities (*tuber maxillae*), the width of the braincase (*neurocranium*), the lateral length of the viscerocranium measured from the beginning of the skull to the beginning of the zygomatic arch (*arcus zygomaticus*), the distance from the nuchal crest (crista nuchae) to the end of the nasal bone, and the distance from the nasoincisive notch (*incisura nasoincisiva*) to the medial angle of the orbit (**Fig. 1-3**). Next, the Pearson correlation coefficient was calculated, and a trend line analysis was performed.

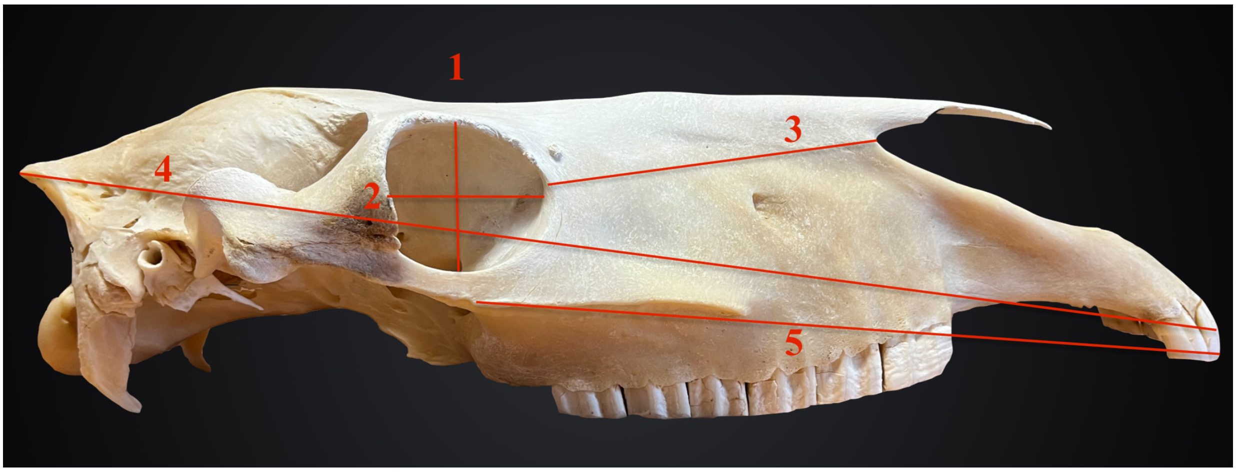


**FIGURE 1** Lateral view of the horse skull (*facies lateralis*). 1 – height of the orbit. 2 – width of the orbit. 3 – nasoincisive notch – orbit. 4 – maximum length of the skull. 5 – lateral length of the viscerocranium

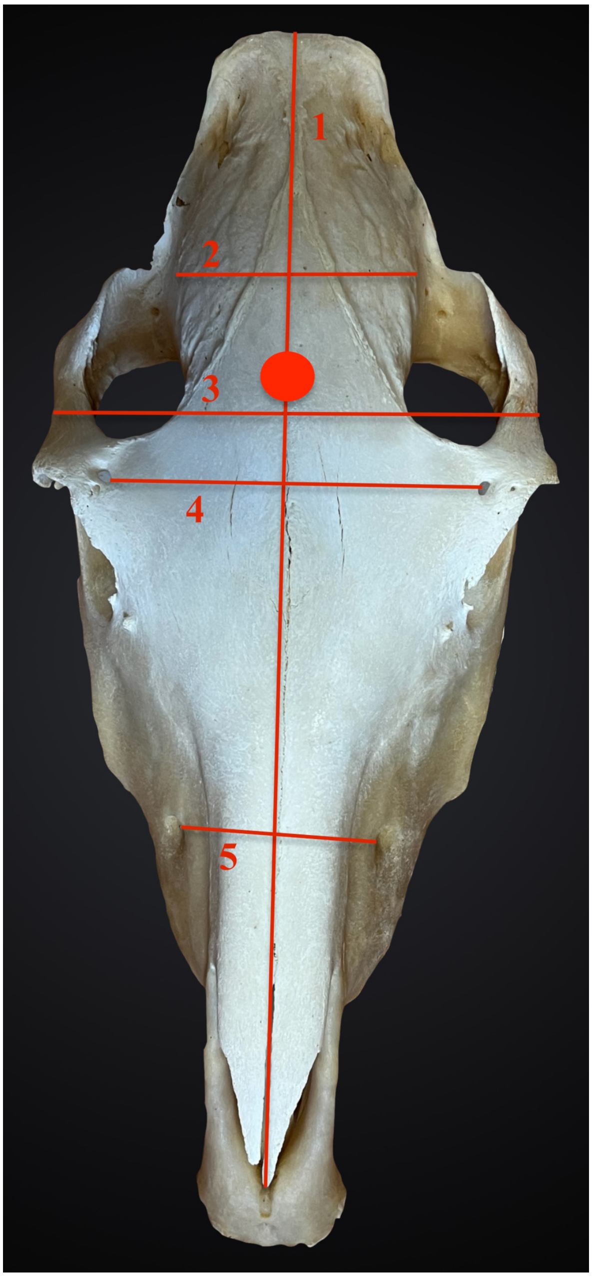


**FIGURE 2** Horse skull positioned dorsally, with a red circle indicating the point of skull penetration. 1 – nuchal crest – end of the nasal bone. 2 – width of the braincase. 3 – width of the forehead. 4 – distance between the supraorbital foramina. 5 – distance between the infraorbital foramina

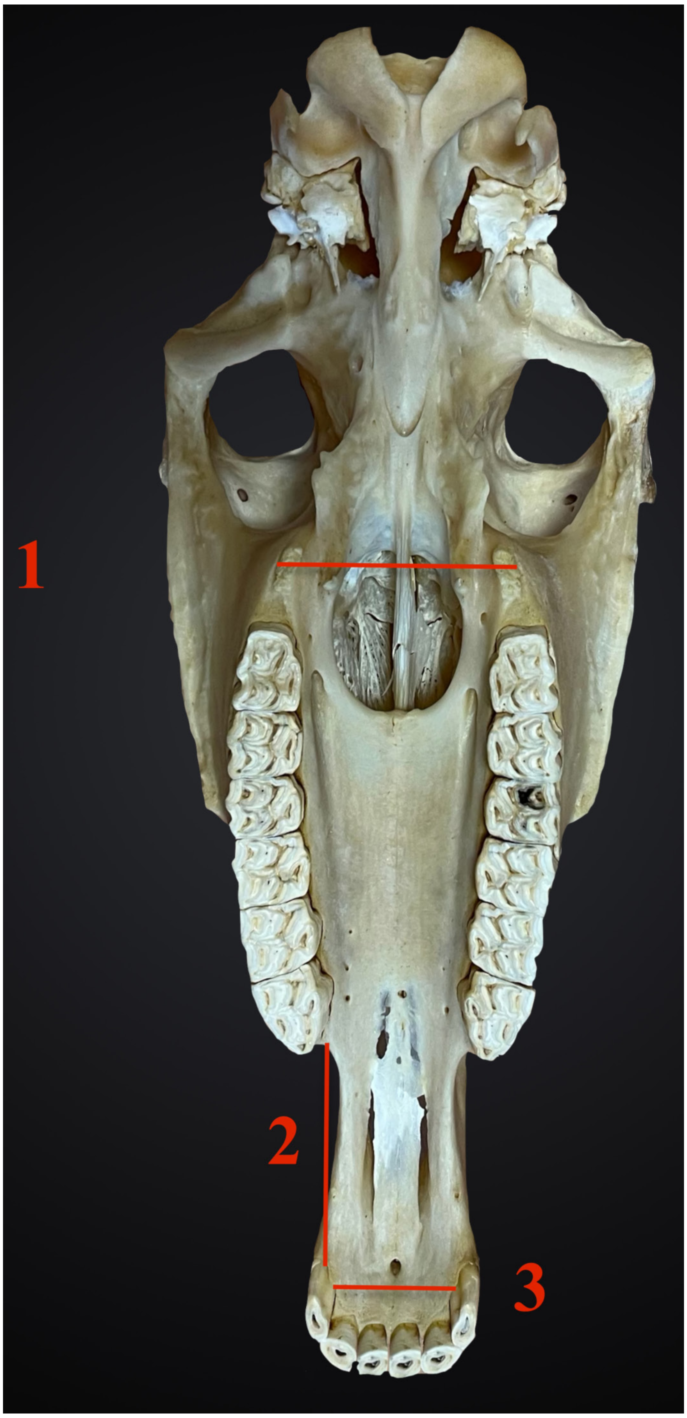


**FIGURE 3** Horse skull positioned ventrally. 1 – distance between the maxillary tuberosities. 2 – length of the diastema. 3 – distance between the alveolar boundaries of the third incisor

## Results

The average thickness of the frontal bone at the point of impact by the stunning device was 6.163 mm. Other average measurements were as follows:

- maximum width of the entire skull – 222.3 mm
- maximum height of the entire skull- 149.9 mm
- maximum length of the skull- 571.5 mm
- maximum width of the face- 199.9 mm
- width of the forehead- 181.6 mm
- width of the orbit- 65.403 mm
- height of the orbit – 58.154 mm
- distance between the maxillary tuberosities – 117.3 mm
- width of the braincase- 107.3 mm
- lateral length of the viscerocranium – 355.7 mm
- distance from the nuchal crest to the end of the nasal bone – 496.35 mm

- distance from the nasoincisive notch to the medial angle of the orbit- 167.74 mm
- length of the diastema – 100.276 mm
- distance between the infraorbital foramina – 83.17 mm
- distance between the supraorbital foramina- 151.587 mm
- distance between the alveolar boundaries of the third incisor – 70.383 mm.

The distance between the alveolar boundaries of the third incisor showed the highest correlation, suggesting a strong relationship between the thickness of the frontal bone and the distance between the alveolar boundaries. Similarly, positive correlations were observed for: the lateral length of the viscerocranium, the distance from the nasoincisive notch to the medial angle of the orbit, the distance between the infraorbital foramina, and the height

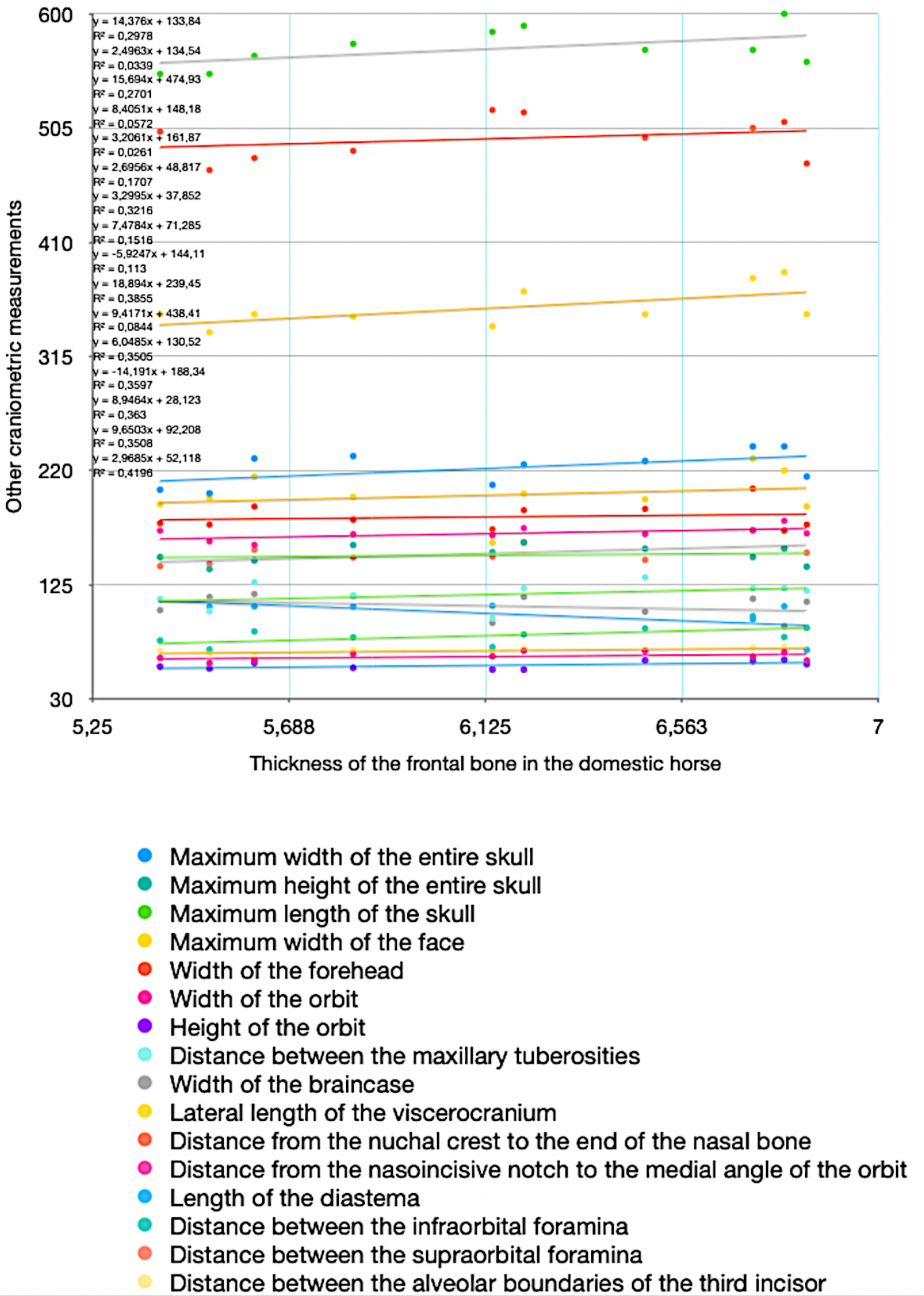


**FIGURE 4** Chart showing trend lines and regression equations based on the thickness of the frontal bone in horses

**TABLE 1** Pearson correlation coefficient relative to the thickness of the frontal bone

| distance between the alveolar boundaries of the third incisor | maximum width of the entire skull | maximum height of the entire skull | maximum length of the skull | maximum width of the face | width of the forehead | width of the orbit | distance between the infraorbital foramina |
|---|---|---|---|---|---|---|---|
| 0.647738 | 0.545749 | 0.184012 | 0.519693 | 0.239253 | 0.161458 | 0.413192 | 0.602501 |

| height of the orbit | distance between the maxillary tuberosities | width of the braincase | lateral length of the viscerocranium | distance from the nuchal crest to the end of the nasal bone | distance from the nasoincisive notch to the medial angle of the orbit | length of the diastema | distance between the supraorbital foramina |
|---|---|---|---|---|---|---|---|
| 0.567072 | 0.389353 | -0.336094 | 0.620897 | 0.290548 | 0.592044 | -0.113605 | 0.592289 |

of the orbit. Negative correlations were noted for, among others, the width of the braincase and the length of the diastema. The maximum width of the face, width of the forehead, and distance between the maxillary tuberosities showed low to moderate correlations (**Tab. 1**).

The trend lines suggest possible relationships. For example, it is possible that as the thickness of the frontal bone in horses increases, so does the maximum width of the skull. A similar situation occurs with the length of the diastema. In this case, it is possible that horses with a longer diastema may have a thinner frontal bone (**Fig. 4**).

## Discussion

Many scientists have been investigating various relationships to estimate specific values for years. This study follows a similar premise and aims to serve as a preliminary investigation into the validity of the hypothesis that the thickness of the frontal bone in a given species, in this case, the horse, can be estimated based on other available craniometric measurements, including those obtainable in vivo. Numerous studies based on biometrics exist, such as those by Chrószcz et al. [10], who conducted research on horses attempting to estimate withers height based on internal skull measurements. It has been shown that such studies have practical applications, for example, in archaeological analyses. Another similar study is by Szara et al. [11], which presented the geometry of the skull of the Japanese quail (*Coturnix japonica*) for potential differentiation of sexual dimorphism in birds, which remains a significant challenge in veterinary science today. In anthropology and medicine, biometric analysis of the skull can be used to estimate the heritability of specific craniometric traits contributing to human phenotypic characteristics [12].

Scientific research on frontal bone thickness is quite limited. According to the best available knowledge in the literature, there is only one detailed study focused on equine sinus anatomy in both two-dimensional and three-dimensional contexts. However, these studies do not address the topic of frontal bone thickness [13]. Komosa et al. [9] provides a detailed description of equine skull morphometry. The measurement results from the present study were generally consistent with the findings of Komosa et al. [9]. This study is preliminary and could serve as a basis for building a group of examined horses in terms of cranial measurements related to frontal bone thickness.

## Conclusions

Considering larger research groups, it might be possible to develop models, especially based on correlations and trends, aimed at estimating the potential thickness of the frontal bone in horses. In today's world, where animal welfare should be a priority, it is crucial for people to develop systems that account for every possible exception in order to ensure the maximum reduction of animal suffering, which is unfortunately an inherent element of the animal industry.

**Ethical approval**
The conducted research is not related to either human or animal use.

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**Conflict of interest statement**
The authors declare no conflict of interest.

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