Hoof wall angulation in the horse (Equus caballus)

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Summary

The objective of the study was to determine the variation of hoof wall angles in horses of different types. Seventy-six mares at the ages of 4–13 years were examined. They belonged to four breeds of different origin types: Purebred Arabians, half-bred Anglo-Arabians, primitive Polish Koniks, and Polish Coldbloods. The angles of the toe, of the medial and lateral walls, as well as of the coronary band, were measured in raised fore and hind feet. The hoof wall angulation differs considerably between fore and hind hooves, as well as between horse breeds. Among the breeds studied, the largest differences occurred between the Purebred Arabians and the Coldbloods. The Purebred Arabian hoof has a low toe angle, a low coronary band angle and high quarter angles, unlike the Polish Coldblood hoof, with a high toe, a high coronary band and low medial wall angles. Distinct differences between fore and hind hooves, as well as between the breeds, indicate that the angles of the hoof capsule cannot be considered uniform but these factors should be regarded.

Keywords: breed, capsule angles, horse hoof

The external shape of the hoof capsule is related to the form and functions of the internal structures. Consequently, the proper functioning of the hoof relies to a great extent on its correct conformation and size (14, 25, 28). Abnormalities in the hoof capsule shape are usually connected with limb conformation defects. In turn, changes in the hoof shape have a considerable influence on joint angles in the limb. Such an effect was investigated for instance by raising heels in the hindlimb (19).

The latest research conducted on a database of thousands of Dutch Warmblood horses shows that the heritability of foot conformation traits is moderate: 0.27 for hoof shape, 0.16 for heel height and 0.12 for uneven feet, i.e. for two differently shaped and sized fore feet (6). The genetic correlations of these traits and performance in dressage and show jumping are low. However, Dutch Warmbloods with even feet score better in these disciplines than horses with uneven feet (11). This abnormality has a detrimental effect on the duration of the horse’s competitive life at the elite level of jumping and tends to shorten its competitive life in dressage (7). According to Ross and Dyson (21), uneven feet are more prevalent in lame than in sound horses.

To assess the correctness of the hoof shape, capsule dimensions and angles should be considered. Excellent precision is achieved when measuring the foot conformation with the use of photography or radiography (32). In practice, however, the angles are usually judged visually and only the angle of the toe (the so-called hoof angle) is measured with various hoof gauges (16).

The angle of the toe is formed by the dorsal and the bearing surface of the foot. Externally, it should match the angle of the foot-pastern axis, as well as the conformation of the whole limb. From the internal aspect, the correlation between toe and heel angles, on the one hand, and the angles of the distal phalanx, on the other, is modest (8). A broken foot-pastern axis occurs when the slopes of the pastern and hoof are different. The angle of the toe is lower than normal in a backward-broken hoof, and conversely, it is more upright in a forward-broken or club-footed hoof (3, 23, 31). The foot-pastern axis is sometimes straight, but the whole digit may simultaneously be too sloping (acute) or too steep (stumpy). The angle of the toe does not affect the hoof-flight pattern or the stride length, but it does influence the break-over: a low angle results in a longer period between heel-off and toe-off, whereas a high
angle shortens it (3, 5). Riemersma et al. (20) found that lowering the angle of the toe by trimming and shoeing increased the tension of the deep digital flexor tendon, and conversely, rising the angle decreased the tension. Hinterhofer et al. (13) also observed higher stress in the hoof capsule when the heels and the angle of the toe were lowered. A lower angle of the distal phalanx increases strain in the navicular bone, since the loading of the deep digital flexor tendon is higher (10), and the distal interphalangeal joint angle extension is increased (17).

The angle of the heels being 5° lower than the angle of the toe results in the so-called under-run or collapsed heels. This abnormality occurs often, and if left uncorrected, causes lameness and predisposes to the navicular syndrome (24, 30). Raising the heels will lower the stress, and subsequently hoof capsule deformations will occur more rarely (13). However, with regard to forces applied to the equine foot, the parallelism of the heel and the toe is less important than the angle of the distal phalanx (10).

The angle of the coronary band is formed by the proximal limit of the lateral wall and the hoof ground surface. With regard to the geometry, it is related to the ratio of the toe length to heel length, to the hoof solar length, as well as to the hoof and heel angles. Our earlier studies show that in the normal foot the toe to heel length ratio amounts to 2:1 in both the fore hoof and the hind hoof (26), rather than 3:1 and 2:1, respectively, which was previously accepted as correct (31).

Viewed from the front, the angles of the medial and lateral walls may be considered. They are formed by the quarter at the widest part of the hoof and the ground surface. Toe-in, toe-out, broken-in and broken-out conformations, as well as other limb abnormalities, occur when the axis of the digit is deviated (4). Angular deformities are common, though to our knowledge, the range of the normal angles of the quarter walls remains undefined.

The objective of the study has been to determine the variation of hoof wall angles in horses of different types.

**Material and methods**

The material consisted of 76 brood mares representing four breeds of different origin types: 18 Purebred Arabians (PA), 24 halfbred Anglo-Arabians (AA), 12 Polish Koniks (PK) of a primitive type and 22 Polish Coldbloods (PCB). The mares belong to three selected elite studs which are under ministerial supervision: the studs of PK and PCB of a primitive type and 22 Polish Coldbloods (PCB). The mares belong to three selected elite studs which are under ministerial supervision: the studs of PK and PCB of a primitive type and 22 Polish Coldbloods (PCB). The mares were classified into three age groups: 4-6, 7-9 and 10-13 year olds (Tab. 1).

An essential condition for entering the elite group is the correct conformation. In routine trimming performed once every 6 weeks, the system commonly approved in Poland. Trimmers followed the same rules and standardized the trimming to straight hoof-pastern axis. The mares were properly fed, unshod and self-exercised by regular turn-out in an open field.

The data was collected during the routine trimming of the hooves. The following four angles of the walls were measured with 1° accuracy just after trimming in the left fore hoof and the left hind hoof: (1) the angle of the toe, (2) the angle of the medial wall, (3) the angle of the lateral wall and (4) the angle of the coronary band (Fig. 1). The angles were measured with the hoof protractor. We aimed at measuring raised feet, as it is commonly done by practitioners. In radiograph *in vivo* studies, the hoof is usually examined in the standing horse, when the body mass loads the hoof, and the capsule angles are affected. The shoe-shaped bottom of the device was put closely to the solar surface of the lifted hoof, whereas the measuring arm ran along the middle of the toe and across the medial or lateral wall at the widest part of the hoof, respectively (Fig. 2). In the case of the angle of the coronary band, the protractor shoe was lengthened by a thin backing and this bottom part of the device was placed on the solar surface of the raised hoof. The measuring arm ran along the coronary band at the lateral wall.

Each angle was statistically processed by multi-factor analysis of variance (22). The following factors were considered: fore/hind hoof, horse breed, horse age group, interaction between the fore/hind hoof and the breed, as well as interaction between the fore/hind hoof and the age group. The results are presented as Least Square Means (LSM) and Standard Errors (SE). The significance of differences was estimated with Tukey’s test.
Results and discussion

The fore/hind hoof effect was important in the case of the toe, lateral wall and coronary band angles (Fig. 3). The angle of the toe in the fore hoof was lower than in the hind hoof (49.8°, 51.3°, respectively; \(P \leq 0.01\)). The angle of the medial wall did not differ significantly between the two hooves and ranged slightly over 78°. The lateral wall was steeper in the hind hoof compared with the fore hoof (76.2°, 73.7°; \(P \leq 0.01\)). Likewise, the angle of the coronary band was higher in the hind hoof than in the fore hoof (26.5°, 25.3°; \(P \leq 0.01\)).

The horse breed factor significantly influenced the hoof angles. The angle of the toe was lower in the PA and the PK than in the AA and the PCB (Tab. 2). The PCB had the highest toe angle. With regard to the medial wall, the largest difference occurred between a high angle in the PA and AA and a relative low angle in the PC. The PA, AA and PK horses did not differ significantly in this respect. The angle of the lateral wall was also the highest in the PA. Like the toe angle, the coronary band angle was the highest in the PCB and the lowest in the PK and PA.

The SE in the quarter angles was higher than in the toe and coronary band angles.

The interaction between the fore/hind hoof and the horse breed was considerable for all of the angles (Tab. 3). The angle of the toe was significantly higher in the hind hoof than in the fore hoof in the PCB horses. In other breeds, similar tendencies were insignificant. As to the angle of the medial wall, it was higher in the fore hooves in the PA, whereas in the PCB the hind hooves were steeper. The angle of the lateral wall was lower in the fore limb than in the hind limb both in the PA and PCB. The angles of the medial and lateral walls were similar in the fore and hind hooves in the AA and PK. The fore and hind hooves were alike with regard to the angle of the coronary band in the AA, PK and PCB. In the PA, however, the coronary band angle was higher in the hind limb than in the fore limb.

![Fig. 2. Measurement of angles of the horse hoof: 1 – angle of the toe; 2 – angle of the medial wall; 3 – angle of the lateral wall; 4 – angle of the coronary band](image_url)

![Fig. 3. Angulation (LSM ± SE) of horse fore hoof and hind hoof](image_url)

Explaination: * Difference between fore hoof and hind hoof significant at \(P \leq 0.01\)
The effect of age was not significant for any of the angles measured. No interaction between the fore/hind hoof and the horse age group was observed for any of the angles (Fig. 4, 5).

The similarity of the hoof angles in mares at the ages of 4-6 to 10-13 years shows that the hoof capsule shape does not change over that period. This justifies the choice of the material that was not significantly influenced by the age factor and homogenous in sex.

Many articles documented the proper toe angle in both performance and feral horses (e.g. 1, 10, 19, 28); however, other hoof wall angles have not been extensively studied to date. In the present study, the angles of the toe, of the medial and lateral walls, and of the coronary band were measured in four fundamentally different breeds. Although the variability was found to be high, overall tendencies in the hoof capsule angulation are important not only for scientists, but also for breeders and farriers.

The toe angle in Purebred Arabians, Anglo-Arabians and Polish Koniks evidenced in the study was lower than 52.2° ± 3.7°, found by Dyson et al. (9) in non-lame adult horses. The overall values were also distinctively lower than 51.9°-52.9° in fore hooves and 56.1°-56.6° in hind hooves, found by Oosterlinck et al. (18) in ponies.

The angles of the medial and lateral walls were not statistically compared as two different features. However, the tendency of the medial wall angle to be higher by a few degrees than the lateral wall angle was visible in both hooves, which is consistent with common knowledge about the hoof capsule conformation. The coronary band angle turned out to be lower than the hitherto assumed 30° (29). On the other hand, it was higher than 21.9° – 2.5°, found by Dyson et al. (9) in non-lame adult horses.

The discrepancy in the toe and coronary band angles between horses of various breeds examined in different studies is distinct. To some extent, it may result from the manner of trimming (17). With regard to the angles discussed here, the trimming is likely to influence mainly the toe and coronary band angles, whereas the quarter angles in an adult horse are more

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**Tab. 2. Hoof angulation (LSM ± SE) in horse breeds**

<table>
<thead>
<tr>
<th>Breed</th>
<th>Angle of the toe</th>
<th>Angle of the medial wall</th>
<th>Angle of the lateral wall</th>
<th>Angle of the coronary band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSM</td>
<td>SE</td>
<td>LSM</td>
<td>SE</td>
</tr>
<tr>
<td>PA</td>
<td>49.3^A</td>
<td>0.6</td>
<td>80.5^A</td>
<td>1.1</td>
</tr>
<tr>
<td>AA</td>
<td>51.1^abc</td>
<td>0.4</td>
<td>79.0^A</td>
<td>0.8</td>
</tr>
<tr>
<td>PK</td>
<td>49.2^AB</td>
<td>0.6</td>
<td>78.0</td>
<td>1.1</td>
</tr>
<tr>
<td>PC</td>
<td>52.6^ABC</td>
<td>0.5</td>
<td>76.4^A</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Explanations: A, a – LSMs of an angle marked within a column with the same superscript differ at: capitals $P \leq 0.01$, small letters $P \leq 0.05$

**Tab. 3. Fore hoof and hind hoof angulation (LSM ± SE) in horse breeds**

<table>
<thead>
<tr>
<th>Breed</th>
<th>Hoof</th>
<th>Angle of the toe</th>
<th>Angle of the medial wall</th>
<th>Angle of the lateral wall</th>
<th>Angle of the coronary band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSM</td>
<td>SE</td>
<td>LSM</td>
<td>SE</td>
<td>LSM</td>
</tr>
<tr>
<td>PA</td>
<td>fore</td>
<td>49.1</td>
<td>0.8</td>
<td>84.4^A</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>hind</td>
<td>49.5</td>
<td>0.8</td>
<td>76.7^A</td>
<td>1.5</td>
</tr>
<tr>
<td>AA</td>
<td>fore</td>
<td>51.0</td>
<td>0.6</td>
<td>79.0</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>hind</td>
<td>51.2</td>
<td>0.6</td>
<td>77.1</td>
<td>1.2</td>
</tr>
<tr>
<td>PK</td>
<td>fore</td>
<td>48.5</td>
<td>0.7</td>
<td>77.9</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>hind</td>
<td>49.8</td>
<td>0.9</td>
<td>78.2</td>
<td>1.6</td>
</tr>
<tr>
<td>PC</td>
<td>fore</td>
<td>50.6^A</td>
<td>0.7</td>
<td>73.5^A</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>hind</td>
<td>54.6^A</td>
<td>0.6</td>
<td>79.2^A</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Explanations: A, a – LSMs of an angle in fore hooves and hind hooves marked within a breed with the same superscript differ at: capitals $P \leq 0.01$, small letters $P \leq 0.05$

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**Fig. 4. Angulation (LSM) of fore hoof with regard to the horse age**

**Fig. 5. Angulation (LSM) of hind hoof with regard to the horse age**
constant and less affected by the farrier. However, the higher SE in the quarter angles than in the toe and coronary band angles indicates that individual differentiation between horses in those angles is important.

The higher toe angle of the hind hoof, as compared with the fore hoof, is a well-known conformation trait, hence the result was expected (1, 28). Hind hooves were more upright than fore hooves also in the angle of the coronary band and the angle of the lateral wall, but not in the angle of the medial wall. The differences in the angles of fore and hind hooves result from different functions of the fore and hind limbs and a higher percentage of the body mass supported by the fore limbs than by the hind limbs (2, 12, 25, 26).

Wilson et al. (33) found that increased hoof spread was associated with a low hoof angle. Studies by Moleman et al. (17) and Oosterlinck et al. (18) demonstrated that a hoof with a larger contact area and a lower toe angle was associated with a higher limb load than a more upright hoof with a smaller contact area.

The hooves of the Purebred Arabian and Polish Coldblood horses were the most characteristic in the study: the Purebred Arabian hoof had a low toe angle, a low coronary band angle and high quarter angles, unlike the Polish Coldblood hoof with high toe, high coronary band and low medial wall angles.

The Purebred Arabians differed from other breeds also in terms of fore and hind hooves in detail. The angles of the lateral wall and the coronary band were higher in hind hooves than in fore hooves, whereas the angle of the medial wall was considerably greater in the front. This means that the fore hooves were steeper inside, more acute outside and had a less sloping coronary band, compared with the hind hooves, which were more acute inside, slightly more upright outside and had a more sloping coronary band. Compared with the hooves of other breeds, Purebred Arabian fore hooves were distinguished by an almost vertical medial wall, a steep lateral wall and a more acute coronary band angle, unlike Purebred Arabian hind hooves, which were more acute inside and more upright outside.

These characteristics may be associated with tendencies towards toe-out conformation in the fore limbs and toe-in conformation in the hind limbs. It should be pointed out, however, that the Purebred Arabians, like all the horses studied, were the elite brood mares after selection, hence no important defects occurred. Another reason might be a long-term selection for upright quarters in fore hooves. However, such a selection criterion is not delineated in the Polish Purebred Arabian breeding programme, which includes only a general description of conformation traits in the horse.

Interestingly, only the Polish Coldbloods had distinctly steeper hind hooves compared with fore hooves. These results show that the opinion about the hooves of coldblood horses being flat is true only with regard to quarter fore hoof angles. They were indeed lower than in the other breeds studied. On the other hand, neither the toe and coronary band angles in both hooves, nor the quarter angles in the hind hoof were lower in the Polish Coldbloods than in the other breeds. It is also clear that the angle of the coronary band in the Polish Coldbloods, particularly in the fore hoof, was higher than in the other horses. This agrees with the relatively short heel length found in the Polish Coldbloods (26).

Both the fore and hind hooves of the Anglo-Arabians tended to be more upright in the toe, medial wall and coronary band, but lower in the lateral wall compared with the other breeds. The relatively steep medial wall was similar to that in the Purebred Arabian fore hooves, which may be a consequence of the fact that the descent of the Anglo-Arabians was to a large degree Arabian.

The fore and hind hooves in the primitive Polish Koniks were also alike. With regard to the toe and coronary band angles, they were closer to those in the Purebred Arabians, whereas the quarter angles resembled those in the Polish Coldbloods. Polish Konik hooves are less affected by selection than the hooves of other breeds because these horses more closely stem from wild ancestors (27).

Conclusion

The hoof wall angulation differs considerably between the fore and hind hooves, as well as between horse breeds, but it does not change significantly between the ages of 4-6 and 10-13 years. Distinct differences between the fore and hind hooves, as well as between the breeds, indicate that the angles of the hoof capsule cannot be considered uniform but these factors should be regarded.

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