Nomenclature of equine hoof measurements – a systematic literature review

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Summary: Measurements of equine hooves are taken in order to assess hoof conformation, to describe changes to the hoof during disease or in relation to trimming and shoeing. Unfortunately, the terms used for the different dimensions of hoof structures differ widely. We conducted a systematic literature review with the aim of collecting terms used for hoof measurements, and to analyze the findings. Our body of literature consisted of papers and recommended reference books, written in both English and in German over the past 10 years. More than 600 scientific papers were found using the search string “TITLE-ABS-KEY ((equine OR horse) AND hoof) AND PUBYEAR > 2009 AND (LIMIT-TO (SUBJAREA, "VETE"))” in Scopus®. Additionally, 5 handbooks were taken into account. A total of 80 Distances, 24 Angles, 34 Ratios and 16 Other measures (e.g. area of sole surface, mediolateral hoof balance) were identified. The highest number of entries (49) was recorded for the caudal angle between Pars dorsalis of the hoof and the ground line, termed often as hoof angle, dorsal hoof wall angle, or toe angle (10 English/2 German terms in total). The length of the Facies soleans, Distance between the outer extent of Pars dorsalis and dorsal cortex of Phalanx distalis; and the caudal angle between Margo solearis of Phalanx distalis and the ground line were classified as measures with highly inconsistent nomenclature (terms/entries of measure 16/25, 17/28 and 17/30, respectively). The most consistent nomenclature was recorded for the term Heel length (12/12). One should be aware of the fact that different terms might be used for the same item or that the same term might signify different measures in different publications. Established terms are not always anatomically correct. We recommend defining every used term in detail, in both written form using correct anatomical nomenclature, and in a figure. The same terms should be used in all publications of one working group. Suggestions for consistent terminology of 15 commonly used measurements in English and German are provided in the paper.

Keywords: horse, terminology, hoof, dimension, distance, angle, ratio

Introduction

Dimensions and angles of the equine hoof are measured in order to assess and classify hoof shape (Gordon et al. 2013, Thieme et al. 2015a), to quantify changes developing during training or during the course of an illness and its treatment (Cruz et al. 2006, Decurnex et al. 2009), and to measure the effect of trimming or application of different horseshoes on the hoof conformation (Tanaka et al. 2015, Amitrano et al. 2016, Hagen et al. 2017). Measurements can be taken directly from the living hoof (Bellenzani et al. 2012, Souza et al. 2016), from scaled photographs (Kane et al. 1998, White et al. 2008, Hampson et al. 2010, Dyson et al. 2011), from X-ray plates (Cripps and Eustace 1999, Kummer et al. 2004, Eliashar 2012, Thieme et al. 2015a) and from 3D reconstructions of CT or MRI series (Labens et al. 2013, Grundmann et al. 2015). Unfortunately, the terms used for the different Distances, Angles and Ratios as well as Others (areas, points and axes) of hoof structures differ widely in English and German literature. In some cases, there are even term differences within single chapters of the same handbook (Baxter 2011) and in different publications by the same author (Hampson et al. 2010, 2013). For the definition of measurements, traditional “farrier terms” such as “toe” for Pars dorsalis ungulae are often used (i.a. Stachurska et al. 2011, Holroyd et al. 2013, Lewis et al. 2014, Faramarzi et al. 2017). The consolidated anatomical nomenclature is not always helpful for a clear understanding of literature dealing with hoof biometry.

The aim of our study was to perform a comprehensive systematic review of the recent literature written in English and German, and to collect the terms and definitions used for all assessed measurements of the equine hoof. From this information, a proposal for a standard terminology of the most popular hoof distances and angles shall be developed.

Material and methods

Sources and Search

The database Scopus® (www.scopus.com) was searched using the search string “TITLE-ABS-KEY ((equine OR horse) AND hoof) AND PUBYEAR > 2009 AND (LIMIT-TO (SUBJAREA, "VETE"))” on February, 21st, 2019. 614 Papers published from January, 1st, 2010 to February, 21st, 2019 were con-
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Considered for further analysis. Additionally, five standard books on equine hooves and limbs, recommended by experienced equine orthopaedists available at the Library of the University of Veterinary Medicine Vienna, Austria, were taken into account. The included books were „Adams & Stashaks Lameness in Horses“ (Baxter 2011), „Lameness in the Horse“ (Ross and Dyson 2011), „Equine Podiatry“ (Floyd and Mansmann 2007), „Der Huf“ (Litzke and Rau 2012) as well as “Adams Lahmheiten der Pferde” (Stashak 2010).

All publications were hand-searched individually by LS for the use of internal and external measurements of horse and donkey hooves and their nomenclature. The workflow of the literature review is depicted in Figure 1.

The measurements were itemized and each term, definition and scope of application was listed. Additionally, all distances, angles and terms used more than once were presented graphically.

A list of suggested terms was developed for the most commonly used measurements.

Statistics

The total number of publications found by the search string defined above, and the number and classification of papers meeting the inclusion criteria, were recorded. All publications were classified by the language and type of publication (original and review; books or papers), and the number of publications per category was listed. The average number of measurements per paper was calculated.

The total number of different measurements, the number of measurements per category and the number of terms used for every single measurement was recorded. The most commonly used terms were identified by counting the publications mentioning them. Constant and inconstant use of nomenclature was recorded by comparing the number of entries and the number of used terms. The number and method (text definition vs. scheme) of definitions for each measurement was documented. Latin terms used for hoof structures in this review are based on the Nomina anatomica veterinaria (NAV, 2017) and presented in Figure 2, as well as English and German terms commonly used in a veterinary context.

Results

Search results and statistics

The Scopus® search using the keywords equine/horse and hoof under the subtopic Veterinary Medicine generated 614 papers published within the last ten years. In the first screening, 85 papers with hoof measurements were identified. Eleven publications were excluded, nine because they were written in Portuguese and two because detailed analysis revealed that no measurements were used. Due to the focus of this study on measurements, publications dealing with measures on donkey hooves were included. The full list of 79 publications that were eventually included in this study, i.e. 74 papers which met the inclusion criteria and the five handbooks, is given in Table 1. The assigned numbers will be used as references in the Results section of this study. Sixty-three original papers (2–4, 8, 10, 12–22, 25–34, 36–42, 44–71, 73, 73) and two educational papers with original measurement.
| No. | Citation                  | Digital object identifier (DOI)/ISBN/ISSN                      |
|-----|--------------------------|------------------------------------------------------------------|
| 1   | van Eps 2010             | 10.1016/j.cveq.2009.12.011                                       |
| 2   | Hampson et al. 2010      | 10.1111/j.1751-0813.2010.00554.x                                 |
| 3   | van Heel et al. 2010     | 10.1111/2042-3306.2010.00064.x                                  |
| 4   | Bhattacharjee et al. 2010| 10.1016/j.jevs.2010.05.004                                      |
| 5   | Eustace 2010             | 10.1016/j.cveq.2010.06.005                                      |
| 6   | O’Grady 2010             | 10.1016/j.cveq.2010.04.008                                      |
| 7   | Relly 2010a              | 10.1016/j.jevs.2010.07.013                                      |
| 8   | Relly 2010b              | 10.1016/j.jevs.2010.07.020                                      |
| 9   | Floyd 2010               | 10.1016/j.jevs.2010.10.002                                      |
| 10  | Mansmann et al. 2010     | 10.1016/j.jevs.2010.11.007                                      |
| 11  | Karle et al. 2010        | ISBN 9728988                                                    |
| 12  | Ronchetti et al. 2011    | 10.1136/vr.c5993                                                 |
| 13  | Dyson et al. 2011a       | 10.1111/2042-3306.2010.00162.x                                  |
| 14  | Hampson et al. 2011      | 10.2460/ajvr.779.983                                             |
| 15  | Stachurska et al. 2011   | ISSN 0860437                                                    |
| 16  | Collins et al. 2011      | 10.1111/2042-3306.2010.00312.x                                  |
| 17  | Parés i Casanova 2011    | 10.1016/j.jevs.2011.03.020                                      |
| 18  | Hertich and Teschner 2011 | ISSN 14341239                                              |
| 19  | Clayton et al. 2011      | 10.1111/1.751-0813.2011.00806.x                                 |
| 20  | Ramsey et al. 2011       | 10.1111/2042-3306.2010.00319.x                                  |
| 21  | Dyson et al., 2011b      | 10.1016/j.tvjl.2010.11.015                                      |
| 22  | Parés i Casanova and Oosterlinck 2012 | 10.1016/j.jevs.2011.08.020                                       |
| 23  | Eggleston 2012           | 10.1016/j.cveq.2012.05.001                                      |
| 24  | Elashar 2012             | 10.1016/j.cveq.2012.06.001                                      |
| 25  | Bellenzani et al. 2012   | 10.2460/ajvr.73.11.1735                                         |
| 26  | Hampson et al. 2013      | 10.1111/1.751-0813.2012.00995.x                                 |
| 27  | Gordon et al. 2013       | 10.1016/j.jevs.2012.05.058                                      |
| 28  | Cust et al. 2013         | 10.1111/ajv.12012                                               |
| 29  | Holroyd et al. 2013      | 10.1016/j.tvjl.2012.07.012                                      |
| 30  | Kolstrung et al. 2013    | ISSN 0025-B628                                                   |
| 31  | Meira et al. 2013        | 10.1016/j.jevs.2012.07.001                                      |
| 32  | Patan-Zugay et al. 2013  | 10.21836/Pem20130302                                             |
| 33  | Holden-Douilly et al. 2013| 10.1016/j.hv.2013.02.004                                      |
| 34  | Simonato et al. 2013     | 10.1590/50034-737X201.300300003                                   |
| 35  | Sherlock and Parks 2013  | 10.1111/evh.12065                                               |
| 36  | Weishaupt et al. 2013    | 10.1016/j.tvjl.2013.09.043                                      |
| 37  | Walden et al. 2013       | 10.1016/j.tvjl.2013.09.042                                      |
| 38  | Lewis et al. 2014        | 10.1016/j.jevs.2014.04.010                                      |
| 39  | Taylor et al. 2014       | 10.1016/j.jevs.2013.08.052                                      |

Table 1: Publications included in this study and numerical code for Results. For complete biographical references, see References.
A total of 154 different measurements, falling into the categories: Distances (80), Angles (24), Ratios (34) and measurements of the category Others (including areas, points and axes) (16) were identified. Dimensions which were each mentioned in only one paper, respectively, included 39 of the Distances, 6 of the Angles, 25 of the Ratios and 9 of the category Others. All distances, angles and terms mentioned more than once are summarized in Figure 3. The complete list of measurements and definitions can be found as Supplement 1 (https://www.hippiatrika.com/download.htm?id=20200211). On average, 8 hoof measurements were recorded per publication. In 9 publications the authors recorded only 1 hoof measurement (3, 8, 10, 12, 14, 31, 33, 56, 69), while in 4 publications more than 20 measurements were documented (26, 41, 47, 58). The most commonly used measurements in total were distances $b_{1–3}$ (Fig. 3A) with 32 entries (1, 5, 6, 9, 16, 18, 23, 26, 35, 39–43, 45, 46, 53, 54, 58, 60, 62, 66, 67, 70–75, 77–79), 9 of them in reviews. Distance f (Fig. 3D) could be found 30 times (2, 11, 13, 15, 19, 21, 23, 24, 26, 29, 32, 36–38, 41, 43, 47, 48, 51, 57–60, 63, 64, 74, 75–78), 6 of them in reviews. The highest number of entries (49) was recorded for angle an (Fig. 3D) (2–4, 9, 11, 13, 16, 18–21, 23–30, 33–37, 41, 43, 47, 48, 51–53, 55, 57–60, 62–64, 68, 70–72, 74–79), 10 of them in reviews. The angle ao (Fig. 3C) was found 33 times (2, 6, 9, 13, 16, 19, 20, 23, 26, 35, 39–41, 43, 45, 47, 49, 50, 52–54, 58, 60–62, 65, 68, 69, 71, 72, 75, 77, 79), 7 of them in reviews. Original papers with a high amount of different measurements were for example studies focusing on hoof conformation (2, 26, 29, 41, 58, 64) and on measurements of the equine hoof itself (47). The publications with few measurements investigated research questions with specific problems, as for example the correlation between a particular hoof dimension and lameness (69), ratios of different dimensions in relation to laminitis (73) and the correlation between hoof angles and race performance of the same horse (28).

The number of German scientific publications dealing with hoof measurements was low (18, 32, 43, 45 73, 76, 79) during the studied time period. Nineteen out of the 154 measurements (Fig. 3; $a, b_{1–3}, f, i_{1}, m, n, q, a_f, a_g, a_h, a_m, a_n, a_o, a_e, a_v, a_y, a_z$, not depicted) were included in German publications, all of them were named with German terms. Some papers also provided terms in English (29, 43, 45, 73). Almost a third (7 out of 19) of the measurements in German publications were mentioned in only one review paper (43).

Consistency and inconsistency of nomenclature

English terms for the most common measurements (Fig. 3; $b_{1–3}, f, a_n, a_o$) were used inconsistently. For the distances $b_{1–3}$ (Fig. 3A) with 28 entries (1, 5, 6, 9, 16, 23, 26, 35, 39–42, 45, 46, 53, 54, 58, 60, 62, 66, 67, 70–72, 74, 75, 77, 78) in English publications, 17 different terms were used. For f (Fig. 3D) which was recorded 27 times (2, 11, 13, 15, 19, 21, 23, 24, 26, 29, 36–38, 41, 47, 48, 51, 57–60, 63, 64, 74, 75, 77, 78), 6 terms could be found. The angle an (Fig. 3C) was mentioned in 45 papers (2–4, 9, 11, 13, 16, 19–21, 23–30, 33–37, 41, 47, 48, 51, 53, 55, 57–60, 62–64, 68, 70–72, 74, 75, 77, 78) with 11 noted terms; and for the angle ao (Fig. 3C) 17 different terms were used within a total of 30 entries (2, 6, 9, 13, 16, 19, 20, 23, 26, 35, 39–41, 47, 49, 50, 52–54, 58, 60–62, 65, 68, 69, 71, 72, 75, 77). A frequently used dimension, with an extremely inconsistent use, was the measure c (Fig. 3D), which was mentioned in 25 English publications (2, 13, 15, 19–22, 26, 27, 29, 38, 41, 39, 40, 51, 56–58, 60, 63, 66, 74, 75, 77, 78).
Fig. 3 Measurements in equine hooves: Summary of literature published between January, 1st, 2010 and February, 21st, 2019. Only angles, distances and terms mentioned more than once are shown. X-ray of the left forelimb digit of a horse in [A] lateromedial view, [B] dorsopalmar view and [C] lateromedial view, [D] lateral, [E] dorsal and [F] solear aspect of the hoof (schematics). Legend: a, Vertical distance between Processus (Proc.) extensorius of and the dorsoproximal end of Pars (P.) dorsalis of the hoof [A]; b, Linear distance between the outermost extent of P. dorsalis of the hoof and the dorsal cortex of Phalanx (Ph.) distalis, measured perpendicular to P. dorsalis [A]; c, Length of Facies (F.) contactus of F. solearis [D]; d, Linear distance between the sagittal axis and the widest part of P. lateralis/media[ls] [F]; e, Linear distance between the most dorsodistal extent of P. dorsalis and Apex cunei [F]; f, Linear distance from the most dorsoproximal point of P. dorsalis and along the hoof wall to the ground line [D]; g, Linear distance between the tip of Ph. distalis and the palmaroproximal end of F. flexoria [A]; h, Vertical distance between Proc. palmaris lateralis/media[ls] and the ground line [B]; i1, Vertical distance between the tip of Ph. distalis and the ground; i2, Vertical distance between the tip of Ph. distalis and the distal border of Solea; j, Vertical distance between the distal border of Solea and the ground [A]; k, Horizontal distance between the vertical line at the tip of Ph. distalis and the point of M. soleae at which the hoof tilts during movement (breakover point) [A]; l, Shortest linear distance between the outermost extent of P. lateralis/media[ls] and Ph. distalis, measured perpendicular to P. lateral[is]/medialis [B]; m, Vertical distance between the most dorsoproximal point of Margo (M.) coronalis and the ground line [D]; n, Linear distance between the most palmarolateral-/medial and most distal part of P. mobilis lateralis/media[ls] [D]; o, Vertical distance between the proximal extent of Proc. extensorius and the ground line [A]; p, Distance between the tip of Ph. distalis and the palmarodistal end of Proc. Palmaris [A]; q, Vertical distance between the most palmarolateral-/medial point of M. coronalis at the heel and the ground line [D]; r, Linear distance between the most dorsolateral-/medial point of M. coronalis and the ground line, measured along the hoof wall of Plateralis/media[ls] [E]; s, Linear distance between the palmarolateral and palmaromedial end of F. contactus of F. solearis [F]; t, Horizontal distance between the vertical line at the tip of Ph. distalis and barium marked Apex cunei [A]; u, Linear distance between the most palmarolateral and palmaromedial end of Cuneus ungulae [F]; v, Shortest linear distance between Apex cunei and the line connecting the palmar ends of Cuneus ungulae [F]; w, Linear distance between the dorsoproximal end of Proc. extensorius and the tip of Ph. distalis [A]; x, Horizontal distance between the lateral and medial border of Ph. distalis; x, measured at F. articularis; x, measured at the proximal end; x, measured at the distal end [B]; y, Full circumference of F. solearis [F]; z, Transverse distance between the most convex parts of Tonus ungulae [F]; aa, Distance between the most lateral and most medial part of M. coronalis [E]; ab, Projected length of M. coronalis in lateromedial aspect, measured between the most dorsoproximal and palmarodistal point [D]; ac, Linear distance between the tip of Ph. distalis and the curved palmar end of P. inflexa lateralis/media[ls] at F. solearis [F]; ad, Shortest vertical distance between F. articularis of Ph. distalis and the ground [B]; ae, Longest distance between the proximal and distal end of Os sesamoideum distale, in lateral view [A]; af, Shortest distance between joint surface of Art. interphalangea distalis and the tip of Ph. distalis [A]; ag, Angle between P. dorsalis of the hoof and the dorsal cortex of Ph. distalis [C]; ah, Caudal angle between the dorsal cortex of Ph. distalis and the ground line [C]; ai, Angle between the proximal third to the distal parts of P. lateralis/media[ls] of the hoof wall [E]; ak, Angle of P. lateralis/media[ls] of the hoof wall to the ground line; ak1, measured between the entire P. lateralis/media[ls] and the ground line; ak2, measured between the proximal third of P. lateralis/media[ls] and the ground line [E]; al, Angle between the proximal third to a distal angulation of P. dorsalis of the hoof wall [D]; am, Caudal angle between P. mobilis lateralis/media[ls] and the ground line [D]; an, Caudal angle between P. dorsalis of the hoof and the ground line [D]; ao, Caudal angle between M. soleae of Ph. distalis and the ground line [C]; ap, Caudal angle between the dorsal cortex and M. soleae of Ph. distalis [C]; aq, Linear distance between the tip of Ph. distalis and the point of M. soleae at which the hoof tilts during movement (breakover point) [A]; ar, Angle between M. coronalis and the ground line in lateral aspect [D]; as, Angle between Planum cutaneum and F. flexoria of Ph. distalis in lateral view [A]; at, Angle between Planum cutaneum of Ph. distalis and the ground line in lateralmedial view [C]; au, Angle between F. flexoria of Ph. distalis and the ground line in lateral mediodemial view [C]; av, Angle between a line parallel to Trochlea phalangis mediae and a line parallel to F. articularis phalangis distalis [B]; aw, Angle between the long axis of Ph. media and the line through the tip of Ph. distalis and the middle of Art. interphalangea distalis [C]; ax, Angle between the proximodistal axis of Os sesamoideum distale and the ground line [C]; ay, Lateromedial symmetry: ay1, Angle between the lateral part of Ph. distalis and the ground line in dorsopalmar view [B]; ay2, Angle between a line through foramen solearis of Proc. palmaris and the distal end of Margo coronalis and the ground line in dorsal aspect [E]; az, Full circumference at M. coronalis [F].
in Projektion [E]; ab, Projektioni Länge des M. coronalis in lateralsicht, gemessen zwischen dem dorsoproximalsten und palmarodistalen Punkt [D]; 1, 2, 11, 15, 24, 26, 38, 41, 48, 58, 59, 64, 74, 75, 78) and only three used terms (heel angle, angle of the heel, palmar heel angle). In German publications, every mentioned measurement was defined, either in words, in a figure or both, with the exception of one measure (Fig. 3A; i1) in a single publication (32).

Anatomical and language correctness

Terms for position and direction (e.g. lateral/medial, proximal/distal, palmar/plantar) based on the NAV (2017), as reference work for the standard vocabulary in veterinary anatomy were used in the definitions for 86 out of 110 hoof measurements with written definitions. Latin terms (NAV based) for anatomical structures were used in only 4 publications (18, 43, 45, 73), all of them in definitions in German.

The term “toe”, in German “Zehe”, was used by several authors (i.e. 11, 15, 29, 64, 78) to designate Pars dorsalis of the hoof capsule or even only its dorsodistal tip. The anatomical toe (digitus) is a body part containing Phalanx proximalis, Phalanx media and Phalanx distalis as skeletal structures and surrounding tissues including skin and its derivatives. In the publications analysed for this study, the term sole was often used for the total area of the hoof which is in contact with the ground, as in “sole length” (56) for the distance c (Fig. 3D), “sole width” (22, 64) for the distance d (Fig. 3F) as well as “medial/lateral sole width” (2, 41, 58) for distance d lat/med (Fig. 3F), including Margo solearis of Pars dorsalis, Pars lateralis and Pars mobilis lateralis as well as Cuneus ungulae and Torus cornues.

For terms derived from the anatomical structure sole (Solea), the term “solar”, meaning “of or from the sun” (Cambridge dictionary, 2019), instead of “solear” was used in 22 publi-
For this study, the database Scopus® was searched systematically. Scopus® was chosen because, apart from medicine, it includes a range of scientific journals that are not primarily linked with medicine and therefore not included in the medical standard database MEDLINE®. Since the standard for a systematic literature review is 1–5 databases (Pati and Lorusso 2018), we attempted an overview search on a second database, PubMed®, using the same search string. This search provided fewer results (not shown), but they were not substantially different. Therefore, Scopus® seemed appropriate as a primary source.

### Table 2

| Measure | English term | German term |
|---------|--------------|-------------|
| a Founder distance | Distal displacement | Rehstrecke |
| Wall thickness | Thickness of the dorsal hoof wall | Hufbeinsenkung |
| b Hoof width | Length of the ground bearing surface | Hufbeinrotation |
| c Hoof depth | Dorsal capsular rotation | Rotation des Hufbeins |
| Distal phalanx axis | Angle of the dorsal aspect of the distal phalanx | Hufbeinwinkel |
| Hoof axis | Angle between the dorsal hoof wall and the ground | Hufwinkel |
| Hoof angle | Lateral-medial balance | Seitenliche Hufbeinrotation |

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Books have been included in this search because standard handbooks usually provide an appropriate nomenclature for scientists in the field. We decided to select handbooks based on recommendations of veterinary orthopaedists. We are aware that this choice may be biased by personal preference. While the significance of “Adam & Stashaks Lameness in Horses”, with over 1400 citations by publications listed in Scopus®, is not to be doubted, other books might be preferred by other specialists. The five chosen books cover English and German language as well as literature relevant for clinicians and farriers.

The timeframe of the last ten years was arbitrarily chosen for this study with the aim to map the recent discussion in the field. However, a number of frequently cited papers addressing hoof measurements and nomenclature were not included in the chosen timeframe (Cripps and Eustace 1999, Kummer et al. 2004, Rocha et al. 2004). Moreover, it has to be taken into account that equine orthopedia and pedology date back to ancient times, consequently hoof nomenclature has developed and diversified over centuries in equine medicine and farriery.

The classification between original and review group within the included publications was difficult, as some papers did not meet the standard categories of the journals. An attempt was made to examine each paper for the originality of the measurement data and to assign it to the groups accordingly, as described in Material and Methods. Two papers (Floyd 2010, Eggleston 2012) defined by the editors as clinical technique and review, respectively, were therefore classified as original papers for the purpose of our study.

The number of measurements per original paper ranged widely between one and 32. Papers with a high number of measurements usually dealt exclusively with the hoof (Hamp-Table 3

| Measure | Suggested term English | Suggested term German | Terms used most frequently English, German |
|---------|------------------------|-----------------------|------------------------------------------|
| a       | Founder distance       | Rehestrecke          | Founder distance Rehestrecke            |
| b       | Dorsal hoof wall thickness | Dicke der dorsalen Hufwand | Dorsal hoof wall thickness Hufbein sen kung#, Wanddicke#, Dicke der dorsalen Hufwand#, Parallelität zwischen dorsaler Hufbeinfläche und Vorderwand# |
| c       | Weightbearing length   | Länge der Fußflächen** | Weightbearing length#, Foot length#       |
| d       | Hoof width             | Huf weite**          | Hoof width                               |
| f       | Dorsal hoof wall length* | Länge der dorsalen Huf wand** | Toe length Zehenlänge                    |
| i₁+i₂   | Sole depth             | Sohlentiefe**        | Sole depth                               |
| i₁      | Sole horn thickness*   | Sohlenhorndicke      | Sole depth Sohlenhorndicke               |
| n       | Heel length            | Trachtenlänge        | Heel length Trachtenlänge                |
| q       | Heel height            | Trachtenhöhe**       | Heel height Palmar/plantare Kronsaum hö he |
| aɡ      | Distal phalanx rotation* | Hufbeinrotation | Angular deviation between the dorsal aspect of the distal phalanx and dorsum (dorsal aspect) of the hoof wall Hufbeinrotation |
| aһ      | Distal phalanx angle   | Hufbeinwinkel        | Distal phalanx angle Hufbeinwinkel       |
| aм      | Heel angle             | Trachtenwinkel       | Heel angle Trachtenwinkel                |
| aν      | Dorsal hoof wall angle* | Hufwinkel           | Toe angle Hufwinkel                     |
| aо      | Palmar/Plantar angle   | Palmar-/Plantarwinkel | Palmar angle Palmar-/Plantarwinkel#, Winkel zwischen Margo solearis und Boden#, palmarer Winkel# |
| aγ      | Mediolateral symmetry* | Mediolaterale Symmetrie** | Medial-lateral balance Mediolaterale Verkippung/Imbalance |

# terms used equally often, * term from publications between January, 1st, 2010 and February, 21st, 2019, not most often used, ** new term    | # Begriffe die gleich oft verwendet wurden, *Begriff aus der Literatur zwischen dem 01.01.2010 und dem 21.02.2019, nicht am meisten verwendet **, neuer Begriff
son et al. 2010, Dyson et al. 2011, Holroyd et al. 2013, Thieme et al. 2015a, de Zani et al. 2016, Faramarzi et al. 2017), whereas papers for studies with few hoof measurements included a variety of other dimensions, as for example the relative head size (van Heel et al. 2010), the metacarpophalangeal joint angulation (Hagen et al. 2018) or the length of Phalanx media (Walliser et al. 2018).

Inconsistencies of nomenclature

The lack of a consistent nomenclature, at least for the most commonly used hoof measures, decreases both readability and comparability of publications on this topic. Particularly, nomenclature inconsistencies within standard handbooks (Baxter 2011) represent a major problem, as these publications are used as reference works for individual researchers and clinicians. The inconsistencies probably originate from the fact that the individual chapters were written by different authors (Baxter et al. 2011, Farstvedt 2011, O’Grady 2011) and the editor did not choose to standardise the terms. Various use of terms could also be seen in different publications of the same author (Hampson et al. 2010, 2013), who may have deliberately changed the term but gave no reason for it. The lack of a standard nomenclature leads also to homonyms, as seen for the term “toe length”. Interestingly the double use of one term (Fig. 3A, D; f, aq) was recorded in the same publication (Hampson et al. 2013a).

In contrast, there seems to be a general agreement regarding the terminology for structures of the heel, since the terms describing its biometry are very constant (Fig. 3D; n, am).

Of the terms for measurements given in the German language, only 5 of 19 terms were used twice or more. However, the number of German publications analysed for this study was too small for a definite conclusion regarding the consistency of terminology.

Definition of measures

For the sake of repeatability and comparability of research, definitions of recorded measures should be as unambiguous as possible. A description either solely by words or exclusively by a figure seems insufficient. For the purpose of this study, it was very difficult to understand the definitions of the measurements based on only one kind of description or to assign them correctly at all. Interestingly, almost all terms in German publications were defined in detail, with only one exception (\( f, \) Fig. 3A, Patan-Zuga et al. 2013). In English publications, approximately the same number of authors have given the definitions either in written form or with a figure (10 and 12 out of 79, respectively). Unfortunately, only 11 out of 79 authors decided to define terms in both ways. In about half of the publications (38 out of 79), authors did not define their terms in a constant form, but used text, figures or no definition at all. The risk for misunderstandings and even mistakes can be expected to be higher when using only one way to demonstrate the measurement: Floyd and Mansmann (2007) termed a measurement “hoof width” although the half-width of the hoof was shown in the according figure. In de Souza et al. (2017) the width of the coronary band in dorsal view was demonstrated in a figure although the measurement was called “coronary band perimeter”. The term perimeter, i.e. the distance around a given two-dimensional object, should be a circumferential measure and was probably meant in this case, based on the measured values for a foal hoof of approximately 19–26 cm.

In 8 out of 79 publications, no definitions of measurements and no reference to definitions in other sources were given. In these cases, repetition of these studies would be very difficult or even impossible.

Anatomical and language correctness

For the description of the hoof and its structures, a consolidated anatomical Latin nomenclature as fixed in the NAV (2017) is available. Alternatively settled English or German nomenclature might be employed. In only a few publications, all of them German, did the authors use the hoof structures’ Latin terms to describe the measurements (Hertsch and Teschner 2011, Hagen et al. 2015, Thieme et al. 2015b, Walliser et al. 2018). This may be based on the fact that German terms for hoof structures are perceived as colloquial, whereas English terms are often very similar to the Latin ones (e.g. Latin: Phalanx distalis, German: Hufbein, English: distal phalanx). Irrespective of the language, it is important to use standard vocabulary for the definition of measurements, especially when there is no standard set of terms to rely on. Interestingly, in neither German nor English is the hoof measurement terminology completely consistent with the canonised anatomical nomenclature NAV (2017). An example is the word toe/Zehe. It is often used for the Pars dorsalis of the cornified hoof capsule as in “toe length” (Hampson et al. 2010, Stachurska et al. 2011, Lewis et al. 2014), “toe height” (Holroyd et al. 2013) or “Zehenlänge” (Patan-Zuga et al. 2013, Thieme et al. 2015b). In the anatomical sense, the toe length would be the distance between Articulatio metacarpa-(metatarso-)phalangea and the dorsodistal tip of the hoof capsule.

Another example is the word “solar” (real meaning of or from the sun), used in English nomenclature to describe the hoof sole (Solea) and related structures. The term was used in 22 out of 79 publications in names for a measurement e.g. “solar length” (Fig. 3D; c) (Parés i Casanova and Oosterlinck 2012, Faramarzi et al. 2018) and also in definitions like “Angle between the solar surface of the distal phalanx and the ground” (Fig. 3C; ao) (de Zani et al. 2016). The use of the term solar instead of solear does not seem to be dependent on whether or not the authors are native speakers/working in countries where English is the main language (Hampson et al. 2010, Collins et al. 2011, Hagen et al. 2016).

It has to be taken into account that measurements defined by the term sole do not include the anatomical sole segment only (Fig. 3D; c, d, \( d_{\text{lateral}} \)) but the complete so-called Facies solearis. NAV (2017) defines Facies solearis as a composite of all structures visible on the ground surface including Facies contactus with Margo solearis, Zona alba, the peripheral zone of the sole and Crura cunei, and Facies fornicens.

However, these “incorrect” terms are well established in farriery and equine medicine. If they are to be used in an ana-
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Conclusion

When reviewing literature or citing papers on hoof biometry, one should be aware of the fact that different terms might be used for the same item or that the same term might signify different measures in different publications. Consistent use of terminology, at least in the frame of one working group, is strongly recommended. A suggestion for the terminology of 15 commonly used measurements in English and German is given in Table 3. It is an attempt to ensure maximal anatomical correctness while taking well-established terms into account. Considering the fact that no standardized nomenclature for hoof measurements exists, in manuscripts dealing with hoof biometry, all measures should be described and defined in great detail. For this purpose, orientation towards the well-defined veterinary anatomical nomenclature (NAV) might be helpful.

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