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Science: Overview

Equine conformation: clues to performance and soundness?

Introduction

The horse was domesticated about 5000 years ago (Dunlop and Williams 1996); and it can be presumed that selective breeding started soon afterwards. Apart from behavioural characteristics, selection for which may have played an important role in transition from the wild to domestication, the outer appearance or conformation of the horse has been one of the other potential selection criterion employed. We know nothing about those very early days of horse breeding, but the first written source on the topic, the extensive treatise *De re equestri* by the Greek historian and philosopher Xenophon (430–354 BC, cited by Schauder 1923) indeed goes into detail on good and bad conformation.

Xenophon recognised the role of the hindquarters in the propulsion of the horse and described a great many desirable and undesirable conformational traits. For instance, he favoured a broad, but relatively short lumbar area to a long back, which he viewed as a sign of weakness. He further promoted strong metacarpal and metatarsal bones and an intermediate inclination of the pastern, and emphasised the importance of normally shaped hooves. In his work, Xenophon made a direct connection between conformation and functionality, either in terms of suitability for a certain purpose (i.e. performance), or sturdiness or durability (i.e. injury resistance or soundness). Xenophon's insights and opinions were based empirically, as were those by his distant successors, the '*grands écuyers*' of the 17th and 18th centuries (Cavendysh 1674; De Solleysel 1733; Bourgelat 1750).

Scientific thinking had not evolved enough yet in those days, nor were the technical facilities available for a more exact and quantitative approach.

In more recent times, scientific thinking has changed considerably and technical possibilities have increased enormously. However, apart from a few laudable initiatives, research in the area has been limited thus far and conformation assessment in the horse is still based largely on subjective criteria and empirical evidence. We are far yet from proving with hard data unequivocal relationships between aspects of conformation and performance or risk for injury. Whereas the relationship of conformation with performance is of primary interest to horse breeders and horse owners, the relationship with injury resistance is of direct interest to the veterinary profession. In a time when 'evidence-based veterinary medicine' stands at the forefront, 'evidence-based assessment of conformation' should not lag behind, as it is an essential element of any prepurchase or insurance examination.

Here an overview is given of what has been researched and demonstrated thus far with respect to the relationship of conformation with performance and/or soundness. Then, an analysis is made of what is needed to bring more science into the largely empirical practice of conformation judgement and to what extent these requirements can be met using present-day technology. In conclusion, a somewhat speculative, but educated guess of what the future might bring is presented.

Early research into the relationship of conformation with equine health and performance

When searching modern literature databases, one might conclude that no scientific work has been done in this field until recently. This, however, is not true. After the groundbreaking work of Eadweard Muybridge (1899) and Etienne Marey (1882), who introduced the use of photography for the analysis of equine gaits, the area became a popular research item in pre-Second World War Germany. Most of the work was dedicated to more fundamental items but, especially professor Schöttler's group in Berlin, studied the relationship of conformation and performance intensively. Stratul (1922) and Radescu (1923) looked into the relation between conformation and performance in Thoroughbreds, Bantoiu (1922) in Standardbred trotters and Nicolescu (1923) in Hanovarian Warmbloods.

These studies succeeded in finding a number of morphometric measures that were larger or smaller in better performing horses, but differences were small and the value of the work is hard to assess because no statistical analyses were carried out. Rösiö (1927) from Sweden performed extensive measurements in Standardbred trotters in Sweden and Germany, but also in the US in draught horses and in what we would call today endurance horses, but in fact were cavalry horses that had to cover 60 miles a day for 5 consecutive days. The measurements presented were in great detail and included lengths of limb segments and a large number of joint angles, but with no statistical analysis. In a study on 220 East Prussian cavalry horses, 66 of which were top performers in endurance, hunting, dressage or jumping, Wiechert (1927) found that good performers differed in certain conformational aspects from the others, but again statistical significance is uncertain. In a study on the influence of conformation on stride length, a factor strongly related to performance, in which statistical evaluation is included, Franke (1935) found that the lengths of the bony segments of the limbs are more determining for stride length than joint angles. However, Schmidt (1939) states, after measuring 100 cavalry horses, that there is no conformational parameter that is a reliable predictor of stride length. More than a decade later Wehner (1944) came to the similar conclusion that neither joint angles nor segment lengths are unequivocally predictive for stride length in a study of cold blooded horses. Focusing more on performance *per se*, Afanasieff (1930) reports, in a politically biased study, significant correlations between some morphometric variables and maximal speed in Orlow trotters in the USSR and found higher maximal speed related to a wide, but short, thorax, short metacarpal and metatarsal bones, and small shoulder and coxofemoral angles. Bethcke (1930) reported that speed in Standardbreds is related to relatively long bony segments of the extremities and sharp joint angles. He could, however, not select the best performers on these criteria and warned: "Though the measurements may give us some clues for the judgement of a trotter, performance is in the end more determined by other factors such as training, character, blood line, stamina and condition of the internal organs". The same basic conclusion that no consistent conformational characteristics can be identified that reliably determine performance was reached by Kronacher and Ogrizek (1932) in their extensive work on the relationship of performance with conformation; and by Wagener (1934), who analysed morphometric data of top-level dressage and jumping horses from the Hanover cavalry school.

After the Second World War, the horse fell into decline due to rapid mechanisation and interest in the subject declined. Richter (1953), from the then new Free University in Berlin, was one of the few who continued the prewar line of research in a study on the correlation between conformational traits and performance in American-bred German trotters. In East Germany, von Lengerken and Werner (1969) found that thorax width was the only conformational parameter that has a significant positive correlation with kilometre time in Standardbreds. Dušek *et al*. (1970) did not focus on straightforward performance, but looked at the more fundamental relationship between speed, stride length and stride frequency.

The horse back on stage in the digital era

The glorious comeback of the horse as a sports and leisure animal, which started in the mid 1960s has boosted the research interest in the species. This increasing popularity of the horse coincided with rapid developments in computer technology and a consequent sharp increase in computational power and speed. Both factors contributed synergistically to the start of what has been called the second Golden Age of equine locomotion analysis (van Weeren 2001) and, from the early 1970s onwards, much fundamental work on equine gait was initiated.

Conformation and performance

Initially the relationship of conformation (or gait characteristics) with performance was still largely ignored despite the substantial research on equine gait. Surprisingly, what was done focused until very recently almost entirely on Warmbloods and not on racing breeds, as was the case in the prewar era. In Sweden, Michael Holmström related conformation to performance in Swedish dressage horses and show jumpers. He saw a long, forward sloping femur as one of the most important conformational aspects and observed that the following characteristics are more common in both elite show jumpers and dressage horses, compared to average performers: a sloping shoulder, long humerus, large fore pastern and flat pelvis (Holmström *et al*. 1990). Specifically advantageous to jumping ability are height at the withers, length of the pelvis and a long neck; elite dressage horses have a straight stifle angle and large distance between the wing of the atlas and the mandible (Holmström 2001). The most important angular measurements for elite dressage performance are hindlimb pendulation, femur and pelvic inclination and elbow, carpal, stifle and hock joint angle (Holmström *et al*. 1995). Dressage horses have longer backs than showjumpers, related possibly to the required suppleness in the former (Johnston *et al*. 2004).

Related to conformation, as static variable, is gait, a dynamic variable. Barrey *et al*. (2001) used an accelerometric technique to relate kinetic and temporal stride variables to gallop speed (but not to outcome in real racing). The same technique was used, together with image analysis for conformational measurements, to evaluate differences in conformation and gait between breeds and the consequent aptness for dressage performance. Of 3 groups consisting of French, German and Spanish saddle horses, the German Warmbloods came out as most suitable for dressage activities (Barrey *et al*. 2002). In a study on the possible relationship between conformational traits and jumping ability, Langlois *et al*. (1978) showed some tendencies, but reached no definite conclusion. In a follow-up study, in which free jumping horses were studied with skin markers using photography, the angles of the proximal limbs (scapulohumeral angle and coxofemoral angle) were identified as being discriminative for good performance. Interestingly, judgment by experts appeared to be based on other conformational characteristics and did not correspond well with performance indices (Dufosset and Langlois 1984). In a large longitudinal study on show jumpers, Santamaría and coworkers were able to identify a number of kinematic variables related to performance, and which could already be detected at foal age. Elbow flexion, retraction angle of the hindlimbs and inclination of the trunk with respect to the horizontal, were among the variables related to performance

(Santamaría *et al*. 2002, 2004; Bobbert *et al*. 2005).

Love *et al*. (2006) found a negative influence of various faulty conformations (‘back at the knee’, ‘turned out’) on a number of performance parameters in flat racehorses. However, given the very strong genetic determination of conformation (heritability indices for various conformational aspects of 0.16–1.00 were calculated), it was difficult to determine whether these negative associations were due to conformation *per se*, or to other sire-related influences. In a cohort of 108 National Hunt racehorses, Weller *et al*. (2006a) found significant positive associations between intermandibular width, the flexor angle of the shoulder joint and the coxofemoral angle with performance data.

A top-performing horse is not necessarily a horse with a flawless conformation. This observation, made long ago, can be confirmed every day by critical analysis of the conformation of today’s top horses, and has been validated by scientific research. Holmström *et al*. (1990) showed that there were no significant differences in the prevalence of mild deviations of optimal conformation in elite horses compared to a population performing at a low level.

Conformation and soundness

Whereas entire chapters are dedicated to the effects of conformational defects on soundness in almost all standard texts on horse husbandry or equine surgery and medicine from Xenophon to the most recent textbooks (Stashak and Hill 2002), almost all relationships are empirical and very little hard data are available. Most of the scientific papers on the topic express opinions based on experience rather than fact (Dawes 1957; Pritchard 1965), or are indirect conclusions based on qualitative observations (Beeman 1973). Only recently, more quantitative and/or analytical work has been done in this area. Holmström (2001) saw a more vertically positioned femur in horses affected by recurrent lameness. A small hock angle (sickle-hocked) is, apart from other negative effects on soundness, related to back problems (Holmström 2001). On the positive side, short backs are strong backs, but may also lead to more interference of front and hindlimbs (Pritchard 1965). The negative effect of the sickle-hocked conformation on soundness may be related directly to the biomechanical effects created by this conformation. Gnagey *et al*. (2006) in this issue have shown that in horses with a large tarsal angle less concussion was absorbed during the impact phase than in horses with a small tarsal angle, i.e. with sickle hocks. Here, requirements for an optimal conformation for performance and for soundness might be contradictory. A smaller tarsal angle increases the extensor moment and vertical impulse later in the stance phase, which might be beneficial for some types of performance, but the larger net joint moment may increase the risk for plantar desmitis as well (Gnagey *et al*. 2006).

Dyson and Murray (2001) found no association between any conformational abnormality and the presence of sacroiliacal joint pain in a comprehensive clinical study conducted in a population of 74 horses. Horses with steeper hindlimb pasterns have more soundness problems than horses with a more sloping pastern (Holmström 2001). In a study in Thoroughbreds, Anderson *et al*. (2004) demonstrated that offset knees contribute to fetlock problems and a long pastern increases the risk of front limb fractures. A remarkable observation was that carpal valgus proved protective for carpal fractures and carpal effusion, thus challenging the commonly held view that a straight conformation is the optimal conformation.

In a large study comprising data from almost 4000 Thoroughbred yearlings destined to race on the flat, Love *et al*. (2006) demonstrated a tendency that horses with conformational defects had less chance to race than horses with more regular conformation. Despite the large number, the difference was not however significant. Weller *et al*. (2006a) demonstrated a significant increase of the risk of superficial digital flexor tendon injury with an increase in the angle of the metacarpophalangeal joint and with carpal valgus, thus demonstrating a negative effect of this last conformation where Anderson *et al*. (2004) found it to be protective for another disorder. Risk of pelvic fracture increased with tarsal valgus and decreased with an increase in the coxofemoral angle in the study of Weller *et al*. (2006a).

The toolbox is filling up

To evaluate objectively the relationship between conformation and performance or soundness 2 requirements must be met. First, conformation has to be quantified somehow in an accurate and repeatable way. Second, quantitative data regarding performance or reliable epidemiological data relating to type and incidence of injury should be available.

The second requirement is the least difficult. Ratings and ranking in most equestrian disciplines are quantitative by nature, and, although it is recognised that there are many factors other than the horse itself that determine success in equestrian competition, these quantitative outcome parameters are, when used for sufficiently large groups, suitable to relate to conformational characteristics. Quantitative soundness parameters are less easily available, but there is growing interest in equine epidemiology and the number of retrospective and prospective studies that try to identify risk factors for certain injuries has recently increased considerably (Cogger *et al*. 2006; Murray *et al*. 2006; Verheyen *et al*. 2006). This means that monitoring of cohorts of horses with respect to injury is much better nowadays than it used to be.

The first requirement is much more challenging, even in an era in which all kinds of imaging techniques have reached high levels of perfection. The ideal system should be accurate with a high spatial resolution; it should be not or little sensitive to the stance of the horse (standing square or not); it further should provide 3-dimensional data and, last but not least, data capture should take as little time and effort as possible. Although most of the older literature cited above relied on photographic data, and plain photography or even subjective evaluation is still used in more recent publications (Anderson and McIlwraith 2004; Anderson *et al*. 2004; Love *et al*. 2006; Santschi *et al*. 2006), use of 3D or at least multiple 2D data is unavoidable because many faulty conformations cannot be quantified reliably in 2D only. For example, most toe-out horses have some outward rotation of the lower limb as well. A good example of a sound scientific approach is the triad of papers in this issue by Weller *et al*. (2006a–c).

First, a modern state-of-the-art kinematic analysis technique (Proreflex)[1] is tested extensively and compared to photography as the old gold standard, investigating important items such as inter- and intra-operator variability and the influence of the stance of the horse (Weller *et al*. 2006b). Then, the validated system is used to analyse variation in conformation in a population (Weller *et al*. 2006c). Finally, outcome data with respect to both performance and orthopaedic health are related to the quantified conformational data (Weller *et al*. 2006a). This procedure is scientifically sound, but there are drawbacks as well. Most modern kinematic gait analysis equipment is able to provide 3D data of sufficient quality (Clayton and Schamhardt 2001), but fails when it comes to practicality. These systems require a highly standardised environment to yield repeatable results and they further require, in most cases, laborious preparations of the subject to be measured. If conformation is to be linked to performance or soundness, this can be achieved only in large groups of horses, given the large individual variation and the multitude of factors that determine either performance or soundness. A promising development is the video camera based system that was developed in the veterinary school of Alfort, which permits capture of 3D data while the horse is walking up and down a track that is in the field of view of 4 digital cameras. The system does not use skin markers and data capture takes only a few minutes. It is, therefore, very easy to use during stallion selection or other equestrian events. Data analysis relies on the synchronisation of the 4 films and is done afterwards, thus permitting the measurement of relatively large numbers of horses within a short period without disturbing the event that is taking place (Pourcelot *et al*. 2002a,b; Crevier-Denoix *et al*. 2004a,b, 2005).

Towards evidence-based assessment of performance

Forecasting the future has always been a hazardous adventure, but it takes no crystal ball to predict that, in the foreseeable future, human interest in equestrian activities will remain and probably increase further and that technological development will continue. Despite the strongly traditional character of many equestrian activities and the conservative attitude of many horsemen, technology will take an increasingly important place in the equine industry. Easy-to-use, practical devices are being developed (Parsons and Wilson 2006; Ryan *et al*. 2006) that offer the exciting possibility of a quantitative and accurate analysis of biomechanical parameters of individual horses and the evaluation of the effects of interventions on those parameters, which will eventually find their place in daily practice. Practical techniques for the accurate and quantitative assessment of conformation that can be applied at relatively low cost in large populations are being developed. Once used at a large scale and linked to medical records of type and incidence of injuries sustained employing epidemiological techniques, they will open the possibility for longitudinal prospective studies with sufficiently large numbers of animals to establish reliable risk indices for conformational defects, related to the intended use of the horse. Such data will enable the veterinary profession to estimate much better the relative importance of conformational defects for future soundness in animals offered for orthopaedic examinations.

The relationship of conformation with performance is much more complicated. It is interesting to note that, in many of the studies on the relationship of conformation and performance in the racing breeds, irrespective of the period when they were performed, conformational traits related to respiratory capacity, such as thorax width or mandibular width, rather than relevant orthopaedic parameters, seem to be major determinants of ultimate performance (Afanasieff 1930; von Lengerken and Werner 1969; Weller *et al*. 2006a). However, there are a multitude of factors related to performance. Therefore, as already rightfully pointed out by researchers from pre Second World War, it cannot be expected that single conformational traits can ever be identified having good predictive value for performance. We also should realise that, because of the complexity of performance, we will never be able to identify top-level performers with some degree of reliability based on conformational analysis alone. We can, however, measure conformation (and gait) much better with present-day technology than ever before and, with this help, we could quantify the likelihood of certain conformational traits to influence performance. This can only be realised if simplified, user friendly systems come onto the market that allow for high throughput measurement and analyses. It also requires collaboration by studbooks and other breeding organisations. These could benefit hugely from such an effort as the outcome would allow them better to define their breeding goals and make much more rapid progress in improving their population than is currently the case.

P. R. VAN WEEREN* and N. CREVIER-DENOIX[†]
**Department of Equine Sciences, Faculty of Veterinary Medicine, Utrecht University, Yalelaan 12, NL-3584 CM Utrecht, The Netherlands; and [†]Unité Mixte de Recherche de l'Institut National de la Recherche Agronomique et de l'Ecole Nationale Vétérinaire d'Alfort (UMR INRA-ENVA) de Biomécanique et Pathologie Locomotrice du Cheval, Maisons-Alfort, France.*

Manufacturer's address

[1]Qualisys AB, Sävedalen, Sweden.

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