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The role of conformation in musculoskeletal problems in the racing Thoroughbred

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Summary

***Reasons for performing study*: The relationship of conformation to future potential injury is a standard approach in practise but, at present, is largely based on subjective observations.**

***Objective*: To measure conformation in 3-year-old Thoroughbreds and objectively test its relationship with the occurrence of musculoskeletal problems.**

***Methods*: Conformation measurements were taken from photographs using specific reference points marked on the horses and processed on the computer. Clinical observations were recorded for each horse on a regular basis. Stepwise (forward) logistic regression analysis was performed to investigate the relationship between the binary response of the clinical outcomes probability and the conformation variables by the method of maximum likelihood.**

***Results*: Clinical outcomes significantly ($P<0.05$) associated with conformational variables included effusion of the front fetlock, effusion of the right carpus, effusion of the carpus, effusion of the hind fetlock, fracture of the left or right carpus, right front fetlock problem and hind fetlock problem.**

***Conclusions*: Offset knees (offset ratio) contributed to fetlock problems. Long pasterns increased the odds of a fracture in the front limb. An increase in the carpal angle as viewed from the front (carpal valgus) may serve as a protective mechanism, as the odds for a carpal fracture and carpal effusion decreased with an increase in the carpal angle.**

***Potential relevance*: This study demonstrates relationships between conformation and musculoskeletal disease in the racehorse. The information may be useful in selection and management of the racing Thoroughbred.**

Introduction

Currently, there is a great need for data on musculoskeletal disease of the racehorse and factors that predispose the horse to injury. Racing injuries are not only of concern, but can also adversely affect public perception of racing, which can reflect negatively on an industry that has many positive aspects. The cause of race injuries in the horse is considered to be multifactorial, with genetics, race surface, number of starts, age of the horse, pre-existing pathology, biomechanics (conformation) and trauma being implicated as potential aetiological factors (Magnusson 1985; McIlwraith 1987; Kobluk *et al.* 1990; Mohammed *et al.* 1991; Dolvik and Klemetsdal 1996). Each of these factors needs to be evaluated independently to determine its contribution to the complicated developmental scheme of race injury. Previous studies on the cause of race injuries in the horse have focused primarily on racing surface (Cheney *et al.* 1973; Hill *et al.* 1986), number of starts (Magnusson 1985; Kobluk *et al.* 1990; Dolvik and Klemetsdal 1996) and trauma (Jeffcott *et al.* 1982; Rossdale *et al.* 1985; Johnson 1993; Johnson *et al.* 1994; Peloso *et al.* 1994). There have been no reports on the relationship of overall body conformation to clinical findings in the racing Thoroughbred. Therefore, the aim of this study was to utilise an objective method developed for recording specific body measurements to investigate the role of conformation in musculoskeletal problems in the racing Thoroughbred. The hypothesis was that certain conformations (objectively defined) could significantly contribute to certain musculoskeletal problems.

Materials and methods

Study population

One hundred and fifteen 3-year-old horses bred and reared by the same stable were included in this study. Photographs were taken of horses at age 3 years from 4 different contemporary groups, foaled from 1992 to 1995. All 115 horses had been in training and most had raced. All horses were trained on the same training surface in Chantilly, France.

Data collection

To reduce the subjectivity of evaluating the conformation of horses, a previously documented objective method to obtain absolute figures of specific body measurements and angles was utilised (Anderson and McIlwraith 2004; p 563). Photographs were taken, slides scanned and conformation measured utilising NIH Image programme software[1] as described elsewhere in this issue (Anderson and McIlwraith 2004). The photographs were taken (by the second author) from the left side, front and rear of the horse. Specific reference points were marked on the horses for subsequent image analysis by the first author as described elsewhere

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TABLE 1: Results of multiple logistic regression models (P<0.05)

Clinical outcome	Variable	Model	β	s.e.	Odds ratio	95% Confidence intervals
Effusion left front fetlock	Neck bottom	Left	1.024794	0.381786	5.122	4.2552–6.1858
Effusion right front carpus	Right carpus angle	Right	-0.3922	0.1329	0.68	0.53–0.88
Effusion left front carpus	Days of age	Left	0.00914	0.0045	1.01	1.01–1.02
	Front dorsal/palmar ratio		3.7054	1.4364	40.67	2.44–679.09
Effusion left hind fetlock	Rear hoof dorsal angle		0.1667	0.0695	1.19	1.04–1.36
Fracture left carpus	scapula length	Left	-2.56691	1.07365	2.0882	1.2214–3.5066
Fracture right carpus	Right carpus angle	Right	-1.467	0.6634	0.24	0.07–0.85
Right front fetlock disease	Right bench-kneed ratio	Right	2.2409	0.7103	9.41	2.34–37.83
Left hind fetlock disease	Rear hoof dorsal angle		0.1308	0.059	1.14	1.02–1.28

(Anderson and McIlwraith 2004). Conformation variables measured included heights of wither and croup; lengths of topline of neck, bottomline of neck, scapula, humerus, radius, third metacarpus, femur, tibia, third metatarsus, front and hind pasterns and medial and lateral hoof; angles of the scapula (point of withers to greater tubercle of humerus), Scapula I (angle of the scapula; prominence of withers to cranial prominence of greater tubercle of humerus), Scapula II (proximal scapular spine to distal scapular spine), scapulohumerus (shoulder), front and hind pasterns (lateral view), hoof (dorsal, palmar and plantar) radio metacarpal, left and right carpi (as viewed from the front), left and right front and hind pasterns (as viewed from the front or rear) and left and right hocks (viewed from the rear) and measurements to determine degree of offset (bench knee) conformation. Because the photographs from the lateral view were left lateral only and the photographs from the front view included both left and right limbs, results are presented with left and right limbs independent of each other when referring to front view measurements and the lateral conformation variables are related only to left-sided problems.

A radiometacarpal angle >180° represented carpal flexion (over-at-the-knee) and <180° represented hyperextension (back-at-the-knee). As viewed from the front or rear, a pastern angle >180° represented toed-out conformation and <180° represented toed-in conformation. A tarsal angle >180° represented in-at-the-hocks (‘cow-hocked’) conformation and <180° represented bow-legged conformation. A carpal angle (viewed from the front) >180° represented in-at-the-knees conformation (carpal valgus) and <180° represented bow-legged conformation (carpal varus).

In addition to hoof angle measurements, a hoof angle ratio was calculated to determine hoof balance. The hoof angle ratio is the ratio of the dorsal angle to the palmar/plantar angle. A ratio of 1.0 is a hoof with the same dorsal hoof wall angle as that of the palmar/plantar hoof wall; a balanced hoof.

Clinical records

Clinical observations were recorded for each horse by the second and third authors. The second author examined the horses every 2 months during their 3-year-old careers and collated all clinical data. The third author examined the horses at least once per week and communicated with the second author. Clinical conditions (including radiographic diagnoses) recorded included flexor tendonitis, suspensory desmitis, joint effusion, sesamoiditis (radiographic presence of increased vascular channels), curb (swelling over plantar aspect of tarsus), synovial effusion of a tendon sheath, fractures (specific site and type of fracture), surgeries, osteochondritis dissecans (OCD), osteoarthritis, swelling associated with the splint bone (not necessarily active or causing lameness at the time), soft tissue swelling and subjective evaluation of rotation of limbs. Data were recorded for each horse from the records as an ‘event’ or ‘no event’ for presence of each of the conditions. Specific limbs and joints were included in the data set.

Data analysis

Outcomes with frequencies >5% remained in the data set for statistical analysis. In an effort to group outcomes, a ‘fetlock problem’ category was also created to include any one of the following outcomes for the metacarpophalangeal joint: OCD, effusion, persistent swelling of the physes (distal physis of the third metacarpal bone or proximal physis of the proximal phalanx), fracture of the proximal phalanx, sesamoiditis and swelling of a suspensory branch (desmitis).

Stepwise (forward) logistic regression analysis was performed (Version 6.12)^2 to investigate the relationship between the binary response of the clinical outcomes probability and the conformation variables by the method of maximum likelihood. Variables were selected for inclusion in the model based on the χ^2 score statistic and for removal from the model based on the Wald χ^2 statistic. P-to-enter and P-to-remove values were set at 0.05. If no variables proved significant to the model, P-to-enter and P-to-remove values were increased to 0.10 to test for variables close to significance. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to estimate relative risk of musculoskeletal problems. The OR was computed by calculating the exponent of the respective regression coefficient of the variables in the logistic regression model. Odds ratio values > or <1 indicate a proportional increase or decrease, respectively, in odds association with that level of the variable with all other variables held constant. Odds ratios are presented with 95% CI for an increase of 10 cm in length measurements, 1° in angle measurements and a 10% increase in ratios.

Days of age centred to the mean (days of age - mean days of age) was included as a covariate in all models to account for the age variability in the population. To reduce the amount of testing, several different models were developed for certain conformation variables. If the response variable was on the right side (e.g. effusion right front carpus), left-sided conformation variables were removed from the model if they were not related (in this example, the left pastern and left carpus angles remained in the model). Similarly, if the response variable was in the hindlimbs, only hindlimb conformation variables were included in the model. ‘Front’, ‘left’, ‘right’, ‘hind’ or ‘all’ models were used for testing. However, unless otherwise noted, the results are for the left side.

The differences between subjective evaluation of rotation and objective limb angulation measurements were assessed by *t* tests.

TABLE 2: Results of multiple logistic regression models ($P<0.10$)

Clinical outcome	Variable	Model	β	s.e.	Odds ratio	Confidence intervals	P value
Effusion right front fetlock	Right bench knee ratio	Right	1.6276	0.703	5.1	1.29–20.2	0.02
Fracture right front	Right carpus angle	Right	-0.3394	0.1746	0.71	0.51–1.01	0.0519
	Right hoof ratio		-6.6308	3.8056	0	0.01–2.29	0.08
Fracture left front	Scapula length	Left	-2.803704	0.929446	1.97	1.2214–3.0732	0.003
	Front pastern length		5.965948	3.241044	17.927	3.5854–89.832	0.0657
Fracture left front P1	Radial-third metacarpal angle	Left	0.3095	0.1644	1.36	0.99–1.89	0.0598
Physitis right front fetlock	Days of age	Right	-0.0189	0.00927	0.98	0.97–1.00	0.04
	Right carpus angle		-0.5741	0.3164	0.57	0.31–1.05	0.0696
Physitis left front fetlock	Days of age	Left	-0.0288	0.0121	0.98	0.95–1.00	0.02
	Radial-third metacarpal angle		0.4168	0.1898	1.52	1.05–2.21	0.03
Surgery	Fracture left front	All	2.0575	0.8504	7.83	1.48–41.45	0.02
	Fracture left hind		3.4236	1.1537	30.68	3.2–294.38	0.0155
	Front dorsal/palmar ratio		-4.9178	2.2789	0.01	0.01–0.64	0.03

Results

Clinical outcome response variables selected for final model fitting based on frequency (>5%) included flexor tendonitis, fetlock effusion, carpal effusion, tarsal effusion, incidence of fractures in each limb, proximal phalanx fractures, carpal fractures, surgery, physeal enlargement, splints and fetlock indices. Outcomes were also separated by right and left limb designation.

Clinical outcomes that were significantly ($P<0.05$) associated with conformational variables included effusions of a front fetlock, carpus or hind fetlock, fracture of the left or right carpus, right front fetlock problem and hind fetlock problem (Table 1). In an effort to investigate further relationships between clinical outcomes and conformation variables, the P-to-enter and P-to-remove values were increased to 0.10. Clinical outcomes that were associated with conformational variables at this level included effusion of the right front fetlock, any fracture in the left front limb, fracture of the proximal phalanx, physeal enlargement of the left or right front fetlock and surgery (Table 2).

Bottom line of the neck

For every 10 cm increase in length of the bottom line of the neck, the odds of having effusion in the front fetlock increased by a factor of 5.1.

Scapular length

For every 10 cm increment in scapular length, the odds of sustaining a fracture in the carpus decreased by a factor of 0.53. Similarly, for every 10 cm increment in scapular length, the odds of a fracture in the front limb was decreased by a factor of 1.97, assuming the front pastern length held constant ($P<0.10$). For every 10 cm increase in front pastern length, the risk of a fracture in the front limb was increased 17.9 times, scapular length held constant ($P<0.10$).

Angle of the carpus as viewed from the front

For every 1° increase in right carpal angle as viewed from the front: the odds of effusion in the right front carpus decreased by a factor of 0.68: the odds of a right carpal fracture decreased by a factor of 0.24; the risk of physeal enlargement in the right front fetlock decreased by a factor of 0.57, assuming days of age held constant ($P<0.10$); and the odds of a fracture in the right front limb decreased (odds ratio = 0.71), assuming the right hoof ratio held constant ($P<0.10$). The mean ± s.e. right carpal angle from the front for horses (n = 2) with a fracture in the right carpus was 182.38 ± 1.24°, compared to 186.72 ± 1.81° for those horses (n = 112) without a fracture.

Radiometacarpal angle as viewed from the side

For every 1° increase in radiometacarpal angle, the risk of a fracture in the front proximal phalanx increased (odds ratio = 1.36; $P<0.10$); and the risk of physeal enlargement in the front fetlock increased by a factor of 1.52, days of age held constant ($P<0.10$).

Offset knee ratio

For every 10% increase in the right offset ratio, the risk of effusion in the right front fetlock increased 1.18 times ($P<0.10$); and the odds of right front fetlock problems increased by a factor of 1.26.

Hoof angle ratio

The estimated odds ratio when the ratio of the dorsal:palmar hoof angle increased 10% (1/10 of 1 unit increase) was 1.45 for effusion in the front carpus. The same 10% increase in the right hoof angle ratio decreased the odds of a right front limb fracture by a factor of 0.52, right carpal angle held constant ($P<0.10$); and decreased the odds of having surgery by a factor of 0.62, assuming no fracture in the front or hind limbs ($P<0.10$). For every degree increase in hind dorsal hoof angle, the risk of effusion in the hind fetlock increased 1.19 times and the risk of hind fetlock problems increased by a factor of 1.14.

Surgery

The odds of having surgery increased 7.83 times for horses with a fracture in the front limb and 30.68 times for horses with a hindlimb fracture (n = 5), all other variables in the model held constant ($P<0.10$).

Conformation variables that did not affect clinical outcomes in this study ($P<0.05$) include wither and croup height, lengths of topline of neck, humerus, radius, third metacarpus, femur, tibia, third metatarsus and pastern, and angles of scapula (Scapula I and II), scapulohumerus, pastern, hoof and tarsus.

Discussion

The method used for measuring conformation provided an objective means of investigating the relationship between conformation and clinical conditions, as most reported relationships are based upon logical hypotheses and practical experience (Green 1969; Beeman 1973; Stashak 1995). The photographs were left lateral only, as horses are commonly assessed for conformation subjectively from the left side and it was more practical in taking the 3 photographs at the stable and (or) farms. While it is recognised that it is theoretically possible for there to be some differences if lateral views were taken from the right side, the authors consider these to be minimal, and the front and rear views help control for such variability. It is also to be noted that conformation evaluated from measurements of the lateral photograph were related only to left-sided clinical problems.

Conformation variables associated with metacarpophalangeal (fetlock) joint problems (effusion, proximal phalanx fracture and physeal enlargement) included neck bottomline (OR = 5.1 for fetlock effusion), hind dorsal hoof angle (OR = 1.14 for hind fetlock effusion), right offset ratio (OR = 1.18 for right front fetlock effusion), right carpal angle (when viewed from the front) (OR = 0.57 for right front fetlock physeal enlargement) and radiometacarpal angle (OR = 1.52 for front fetlock physitis). When a category was created for fetlock problems, the right offset knee ratio increased the odds of fetlock problems in the right front fetlock by a factor of 1.26 for every 10% increase. For every degree increase in the hind dorsal hoof angle, the risk of hind fetlock problems increased by 1.14 times. It is not surprising that the highest frequencies of all clinical outcomes were those of effusion in the front fetlock joints (28 and 31% for right and left fetlocks, respectively), because many horses in training develop heat and synovial effusion along with varying degrees of lameness.

The effect of length of the bottomline of the neck on fetlock problems is interesting and could be related to increased weight. As the hind dorsal hoof angle increases, compressive forces within the hind metacarpophalangeal joint may increase, causing subsequent effusion. As the front limb becomes more offset, it is logical to assume that tension/compression may increase distally and pain and/or effusion from improper distribution of force down the front limb may occur.

Odds of carpal effusion, carpal fracture and a fracture in the right limb decreased as the right carpal angle (as viewed from the front) increased. An increase in the carpal angle by 1° decreased the odds of carpal effusion by 0.68, and of a fracture by a factor of 0.24. This is an important finding in view of the common desire of a buyer for the horse to have a straight leg and the common practice of surgically manipulating carpal valgus to achieve a straight leg. The relationship between an increase in the carpal angle when viewed from the front and a decrease in the odds of physeal enlargement is questionable, as the carpal angle was measured at age 3 years and, presumably, the enlargement is related to physitis that occurred earlier. However, it could imply a biomechanical relationship in the occurrence of physitis. Another study reported angular limb deformities with physeal dysplasia (physitis) in 72.9% of cases treated for developmental orthopaedic disease (O'Donohue *et al.* 1992) and our associations may simply have been one of frequency of both conditions.

Conformation variations reported to be presumably important in the occurrence of carpal fractures include the morphology of the carpus, foot and lower limb, particularly long toes, low heels and long sloping pasterns (Barr 1994). Although not associated with fractures, the odds of effusion in the left front carpus increased for every 10% increase in the dorsal:palmar hoof angle ratio, meaning that as the heels become more 'underrun' compared to the dorsal surface, the odds of effusion increases. This indicates the importance of correct dorsal:palmar balance in the hoof. It is interesting to note that hoof angles did not affect musculoskeletal disease in the study, but a change in the hoof angle ratio, i.e. balance, did.

The odds of decreasing fractures in the carpus were associated with an increase in scapular length and in the radiometacarpal angle (when viewed from the side). Although carpal hyperextension has been hypothesised to predispose to carpal chip fractures (Beeman 1973; Goodman and Baker 1990), it has been shown radiographically that horses with carpal chip fractures were not significantly more hyperextended than those without (Barr 1994). Although many horses return to racing following removal of osteochondral chip fractures in the carpus (McIlwraith *et al.* 1987), further investigation is warranted to determine the relationship between carpal conformation and carpal chip fractures. Horses with longer shoulders had decreased odds of a front limb fracture (OR = 0.50) and those with long pasterns had increased odds of a front limb fracture (OR = 4.55; $P<0.10$). However, the scapular and front pastern lengths were both correlated with wither height for 3-year-old horses ($r = 0.70$ and 0.65, respectively). The higher odds associated with length of pastern indicate that this conformation may play a more important role than length of the scapula. Long sloping pasterns have previously been implicated in the incidence of carpal chip fractures (Barr 1994).

The only means of evaluating rotation in this study was subjectively, due to the 2-dimensional aspect of photographs. The only subjective determination of rotation statistically associated ($P<0.05$) with objectively measured pastern angles was inward rotation of the right front limb. Rotation is a 3-dimensional conformation that was difficult to assess by measuring a 2-dimensional photograph. The use of video and spatial calibration of dimensions might prove useful in future considerations to evaluate rotation of limbs. All mean pastern angles were >180º, representing a toed-out conformation. Another study also reported that outward rotation was normal for the population of horses studied (Holmstrom *et al.* 1990).

There are many conformations hypothesised to be predisposing factors to lameness and musculoskeletal problems that were not reported in this Thoroughbred study but may warrant future consideration. Splints have long been considered to be a result of poor conformation, including offset knees (also supported by the authors' findings) and base-narrow toed-out conformation, in association with interference (Stashak 1995). This bony proliferation can also extend to the third metacarpal bone. A high incidence of osteoarthritis of the distal tarsal joints has been noted in the young Western working stockhorse with poor hindlimb conformation (especially 'sickle' hocks, 'cow' hocks and 'narrow-thin' hocks; Black 1992). The angle of the hock from the lateral view was not measured in this study because of the variation in stance of the hindquarters. Toe angle has been shown to have an effect on the deep digital flexor tendon and extensor branches of the suspensory ligament (Thompson *et al.* 1993). Deep digital flexor tendon strain decreased as toe angle increased from 55–78°. Strain of the extensor branch of the suspensory ligament increased rapidly when toe angle increased. Further, conformational abnormalities of the foot, especially foot imbalance, may predispose to the development of pain associated with the distal interphalangeal joint (Dyson 1991). With larger numbers, further associations might have been made in this study. However, such studies are difficult and time-consuming and require special cooperation between owners, trainers and veterinarians.

This study showed an association between some conformation variables and musculoskeletal problems in Thoroughbred horses. It is to be acknowledged that many of the odds ratios presented in Tables 1 and 2 are close to 1.0, indicating little importance. As more numbers are accumulated, a higher significance may be obtained and more associations made. However, some significant associations were made. Offset knees (offset ratio) contribute to fetlock problems. Long pasterns increase the odds of a fracture in the front limb. An increase in carpal angle as viewed from the front (more in-at-the-knees or carpal valgus) may serve as a protective mechanism, as the odds for carpal fracture and carpal effusion decrease with an increase in the carpal angle as viewed from the front. Perhaps the most important findings from this study are the conformational variables that did not affect musculoskeletal disease, including wither and croup height, lengths of topline of neck, humerus, radius, third metacarpus, femur, tibia, third metatarsus and pastern, and angles of scapula (Scapula I and II), scapulohumerus, pastern and hocks.

Manufacturers' addresses

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