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Radiographic Comparison of Carpal Morphometry in Thoroughbred and Standardbred Race horses

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ABSTRACT

Carpal conformation is thought to contribute to the frequency of carpal pathology so non-invasive measurement of carpal morphometry would be useful to identify joints at risk. However, there are scant radiographic morphometrical details for the carpals of Thoroughbred (TB) and Standardbred (SB) racehorses even though these breeds differ in the incidence of carpal damage. This study aimed to identify morphometrical similarities and differences in carpal conformation in TB and SB. Thirty carpal dorsopalmar radiographs (DP) were collected from 15 TB and 15 SB. All DP radiographs were at zero degrees or within the acceptable range of rotation. Twelve carpal radiographic parameters were selected and measured on each radiograph. Statistical analysis found significant differences in four carpal parameters. These parameters revealed that the middle carpal joint in SB was significantly more angled distomedially whereas the radial distal metaphysis showed a greater distolateral inclination in TB. The radiocarpal and the carpometacarpal articulations exhibited common features in the two groups of horses. These carpal traits in TB and SB highlight their potential association with loading distribution and pathology. Measuring carpi from untrained and injured horses is necessary to establish breed specific features for the ideal carpal conformation in each of these breeds.

1. INTRODUCTION

The carpus is one of the most complicated regions in equine limbs. Its bony components include the distal extremity of the radius, carpal bones (radial, intermediate, ulnar, accessory, first, second, third and fourth carpal bones) and the proximal extremities of the metacarpal bones. The bones are arranged and articulated in three major carpal joints, the radiocarpal joint (RCJ), the middle carpal joint (MCJ) and the carpometacarpal joint (CMCJ) (Dyce et al., 2010). A general equine carpal morphology has been described grossly (Sisson 1975; 1986; Dyce et al. 2010) and radiographically (Oheida et al. 2016) in detail. The description involved a number of carpal features which represented regions of anatomical and pathological interest. Studies which focused on specific anatomical features in particular breeds are very few. A comparative study that compared between carpal morphometries in Thoroughbreds and Ponies reported numerous significant anatomical differences between the two breeds (Abdunnabi et al. 2012). It was suggested that variation in carpal morphological details of each breed was influenced by specific mechanical requirements (Abdunnabi et al. 2012). If so, then it would be reasonable to ask whether a specific carpal conformation with its potential mechanical effects is associated with particular pathology or not. In horses with back at the knee conformation for instance, some authors associate this undesirable conformation with carpal bone chip fractures (Schneider 1979; Stashak and Hill 2002) but others do not (Barr 1994; Weller et al. 2006a). Unfortunately specific morphological traits are scant in the literature and cannot be correlated with either their potential mechanical role or pathological events. The objective evaluation of the characteristic conformation is a complicated process and needs repeatable and quantitative measurement techniques (Love et al. 2006; Weller et al. 2006b).

Since carpal pathology is a major source of lameness among racehorses (Jeffcott et al. 1982; Ramzan and Palmer 2011), equine carpal lesions have been studied in detail. Previous studies reported significant variations in types, locations and severity of specific pathologies between and within equine breeds. In Thoroughbred and Standardbred racehorses for instance there were substantial differences in their susceptibility to carpal fractures. It was reported that in Thoroughbreds chip fractures occurred more frequently in the distal region of the radial carpal bone (Cr) whereas in Standardbreds fractures were mostly seen in the proximal region of the third carpal bone (C3) (Palmer 1986; Pasquini et al. 1997). In the RCJ, fractures of the distal radius and intermediate carpal bone (Ci) were more common in Thoroughbreds than in Standardbred horses (Palmer 1986). In comparisons within the breeds, SB had a greater incidence of bilateral fractures of C3 than TB (Schneider et al. 1988). It was reported that MCJ had the greatest incidences of carpal fractures among the three main carpal joints, followed by RCJ in both the breeds (Palmer 1986). The varied carpal pathology between and within the breeds has been correlated to several factors such as racing gait, speed, track surface and conformational defects (Palmer 1986; Bramlage et al. 1988; Nunamaker et al. 1989). However, the evaluation of the probability of specific or breed-specific carpal features as a predisposing factor for specific injuries has been neglected. This may be because of the lack of objective conformational data in the literature.

Thoroughbreds and Standardbreds have been selected for racing. However, each breed has a different racing gait. Thoroughbreds race faster but at a relatively short distance whereas Standardbreds are generally trained for a longer distance. Thoroughbreds are galloping during racing which is an asymmetrical gait where a single lead forelimb is on the ground at certain times and the two forelimbs are loaded differently, whereas Standardbreds are trotting or pacing which symmetrical gaits are using both forelimbs similarly during the supporting phases of the stride. Such differences in gait, speed and distance of racing might indicate the presence of specific and compatible morphological features in each breed. Accordingly, it could be reasonable to ask to what extent could the type of racing affect specific morphometry in the carpus. In relation to the association between specific features and horses' performance within the same breed, it was suggested that the presence of some genes which controlled a wide range of anatomical, metabolic and physiological adaptations, influenced the racing performance in racehorses (Bower et al. 2012). Thus, associations between conformational traits and racing performance have been evaluated in different studies and some traits showed strong heritability (Love et al. 2006). Other traits attributed the significant association between racing performance and conformational defects to genetic influences (Naccache et al. 2018). Therefore, the differences in the morphology and the pathology of the carpal bony components between TB and SB are likely to be due to both environmental and genetic factors.

Although carpal conformation might be a causative agent for the varied incidence of carpal damage as well as evaluating the horse quality for purchase, specific carpal traits for TB and SB have not been reported in any radiographic study using DP radiographs. Identifying specific features in each breed seems likely to not only help to explain the disparity in carpal injuries that may be due to the different mechanical forces associated with their different racing gaits, but also for predicting the risk of developing injuries in these breeds. The current study hypothesized that there would be both conformational similarities and differences between the two racing breeds. Therefore, the aim of this study was to identify the radiographic differences and similarities in the carpal morphometry between Thoroughbreds and Standardbreds racehorses.

2. MATERIAL AND METHODS

2.1. Horses and Radiographs:

30 dorsopalmar (DP) carpal radiographs from 30 adult horses were used. 15 radiographs were from Thoroughbreds (7 right and 8 left) and 15 were from Standardbred racehorses (8 right and 7 left). The means

of their ages were 6.5±2.17 in Thoroughbreds and 4.7 ± 1.39 in Standardbreds. The radiographs were collected from the Veterinary Clinic and Hospital in The Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, The University Veterinary Teaching Hospital in The University of Sydney, and private racehorses. All horses were free from any clinical signs of carpal pathology based on their medical reports. The radiographs had to be of a good quality and include all carpal bones, distal radius and proximal metacarpal bones. All DP radiographs had to be at zero degree (ZDP) or within the acceptable rotational range according to Oheida et al. (2016).

2.2. Carpal parameters:

Twelve carpal radiographic parameters were selected to be measured in the study (Abdunnabi 2011; Oheida et al. 2016). All the parameters were designed as angles. Each parameter was formed between two lines extended perpendicularly from two specific features. Each feature was determined by drawing a transverse line extended between two bony landmarks. All the angular measurements were taken towards the medial side.

The twelve carpal parameters (Figure 1) were:

1. Radial metaphyseal-Radial carpal joint angle (Ra.met-RCJ angle)
2. Radial metaphyseal-Middle carpal joint angle (Ra.met-MCJ angle)
3. Radial metaphyseal-Radial facet C3 angle (Ra.met-Rf.C3 angle)
4. Radial metaphyseal-Proximal third metacarpal angle (Ra.met-Prx.Mc3 angle)
5. Radial carpal joint-Middle carpal joint angle (RCJ-MCJ angle)
6. Radial carpal joint-Radial facet C3 angle (RCJ-Rf.C3 angle)
7. Radial carpal joint-Proximal third metacarpal angle (RCJ-Prx.Mc3 angle)
8. Middle carpal joint-Disto-dorsal C3 angle (MCJ-Dis.dor.C3 angle)
9. Middle carpal joint-Proximal third metacarpal angle (MCJ-Prx.Mc3 angle)
10. Radial facet C3-Proximal third metacarpal angle (Rf.C3-Prx.Mc3 angle)
11. Radial facet C3-Disto-dorsal C3 angle (Rf.C3-Dis.dor.C3 angle)
12. Disto-dorsal C3-Proximal third metacarpal angle (Dis.dor.C3-Prx.Mc3 angle)

2.3. MEASURING CARPAL PARAMETERS

All the collected radiographs were entered into the EponaTech Metron (EponaTech Metron, Metron-Hoof, Version 6.06, EponaTech LLC, USA). They were labeled and saved before measuring the carpal parameters. Adjustment of the contrast of the radiographs was conducted whenever it was required. The Free Mark-Up Utility was used to conduct the measurements. To decrease the risk of errors associated with fatigue, no more than 8 radiographs were measured in a single day. All measurements in the experiment were conducted by the first author.

2.4. Statistical analysis

A two way ANOVA was used to compare between the two groups of horses and within each parameter. P values < 0.05 were considered to be statistically significant.

3. RESULTS

The statistical analysis showed similarities and significant differences in the radiographic carpal morphometry between Thoroughbreds and Standardbred racehorses (Table 1). The significant variations were found in four carpal parameters from the total twelve parameters. They were Ra.met-Prox. Mc3 angle, MCJ-Dis.dor.C3 angle, MCJ-Prox.Mc3 angle and Rf.C3-Dis.dor.C3 angle. The greatest variation was in MCJ-Dis.dor.C3 angle (P value = < 0.0002) in which the means were 183.39° ± 1.00 in Thoroughbreds and 181.86° ± 0.95 in Standardbreds. In respect to the similarities between the two breeds, the greatest similarity was seen in the RCJ-Rf.C3 angle. Its mean was 189.87° ± 1.46 in Thoroughbreds whereas in Standardbreds it was 190.17° ± 1.75 with a mean difference of 0.30° (Figure 2).

In regard to the range of measurements in each parameter, it was noted that the range between the highest and the lowest values varied among the parameters. The smallest range of the measurement (3.8°) in all the horses was in Dis.dor.C3-Prx.Mc3 angle. Whereas, the largest range (9.4°) was in Ra.met-Rf.C3 angle.

Table 1. The means (± SD) of twelve carpal parameters used to measure carpal morphometry of 30 dorsopalmar radiographs collected from 15 Thoroughbreds (TB) and 15 Standardbred (SB) racehorses.

Breed		Ra.met-RCJ angle	Ra.met-MCJ angle	Ra.met-Rf.C3 angle	Ra.met-Prox.Mc3 angle	RCJ-MCJ angle	RCJ-Rf.C3 angle	RCJ-Prox.Mc3 angle	MCJ-Dis.dor.C3 angle	MCJ-Prox.Mc3 angle	Rf.C3-Prox.Mc3 angle	Rf.C3-Dis.dor. C3 angle	DisDorC3 -PrxMc3 angle
TB	Mean	182.58	190.04	192.45	185.51*	187.46	189.87	182.93	183.39**	175.47*	173.06	180.98*	172.08
	SD	1.24	2.18	2.21	2.28	1.15	1.46	1.42	1.00	0.98	1.63	1.51	1.06
SB	Mean	181.82	189.43	191.69	183.75	187.92	190.17	182.23	181.86	174.32	172.07	179.61	172.45
	SD	1.24	1.80	2.54	1.81	1.07	1.75	1.06	0.95	0.81	1.79	1.95	0.62
Mean Difference		0.76	0.61	0.77	1.76	0.46	0.30	0.69	1.52	1.15	0.99	1.36	0.37
Range within all horses		5.49	7.6	9.4	9.06	5.08	7.48	5.73	4.56	4.11	7.38	7.26	3.8

SD: Standard deviation

*: Show significance differences (P<0.05) between Thoroughbreds and Standardbreds

*: P<0.05; **: P<0.001

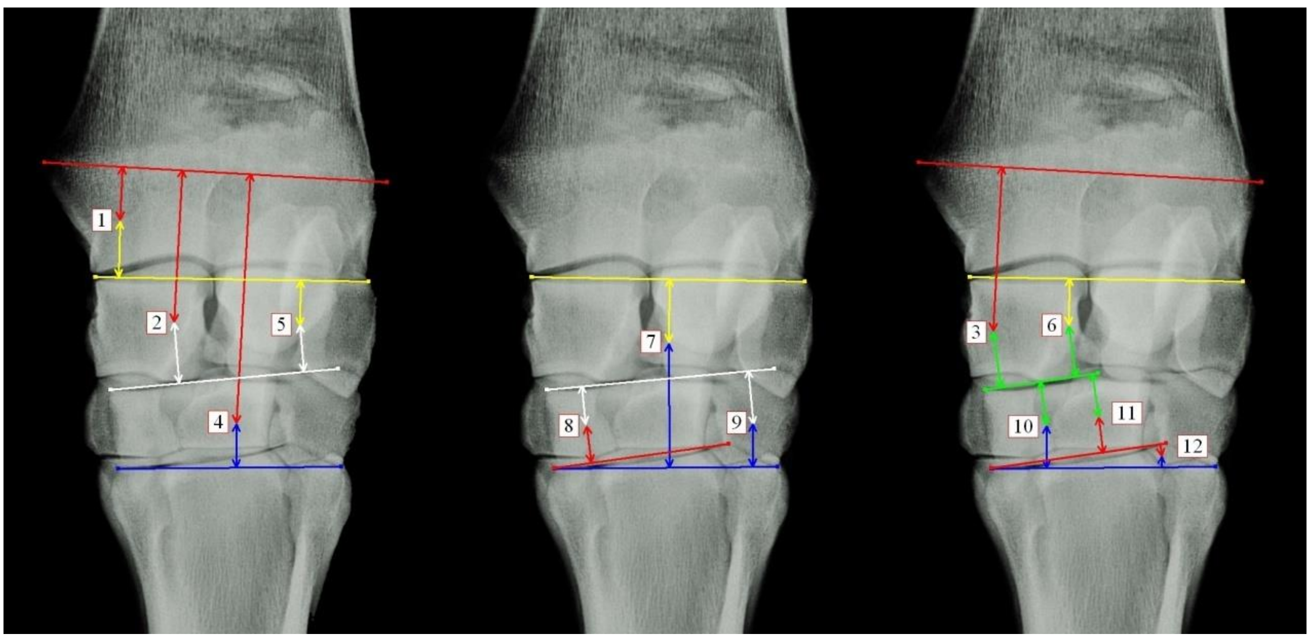

Figure 1: Dorsopalmar radiographs of a left carpus of a Thoroughbred. They show the carpal parameters. 1. Radial metaphyseal-Radial carpal joint angle, 2. Radialmetaphyseal-Middle carpal joint angle, 3. Radial metaphyseal-Radial facet C3 angle, 4. Radialmetaphyseal-Proximal third metacarpal angle, 5. Radial carpal joint-Middle carpal joint angle, 6. Radial carpal joint-Radial facet C3angle, 7. Radial carpal joint-Proximal third metacarpal angle, 8. Middle carpal joint-Disto-dorsal C3 Angle, 9. The Middle carpaljoint-Proximal third metacarpal angle, 10. Radial facet C3-Proximalthird metacarpal angle. 11. Radial facet C3-Disto-dorsal C3 angle, 12. Disto-dorsal C3-Proximal third metacarpal angle. (Adapted from Oheida et al. 2016)

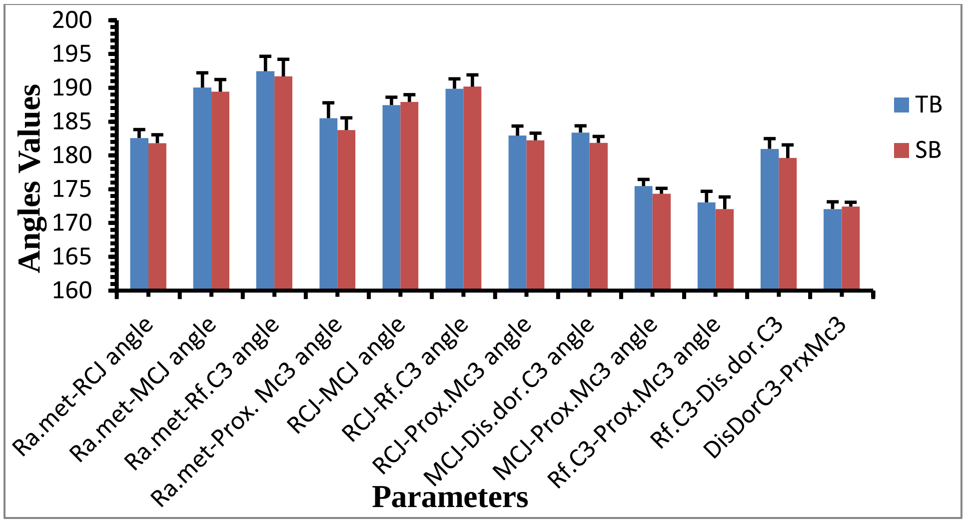

Figure 2. The chart shows the means (± standard deviations) of the twelve carpal parameters. The measurements were conducted on dorsopalmar radiographs of 15 Thoroughbred (TB in blue) and 15 Standardbred (SB in red) racehorses. The significant variations were found in Ra.met-Prox. Mc3 angle, MCJ-Dis.dor.C3 angle, MCJ-Prox.Mc3 angle and Rf.C3-Dis.dor.C3 angle ($P<0.05$).

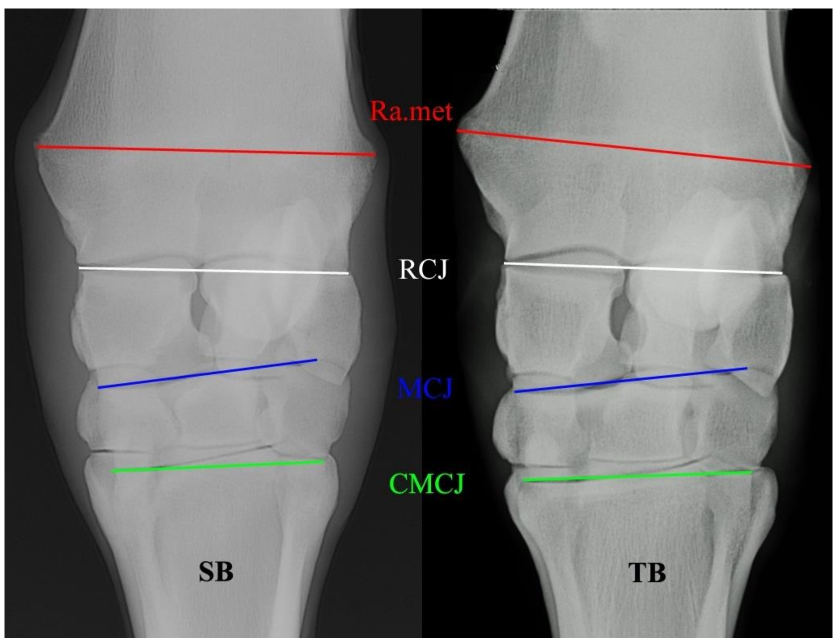

Figure 3: Dorsopalmar radiographs showing the radial metaphysis (Ra.met), the radiocarpal joint (RCJ), the middle carpal joint (MCJ) and the carpometacarpal joint (CMCJ) features in a normal right carpus of a Thoroughbred (TB) and a normal left carpus of a Standardbred (SB) racehorses. The Ra.met feature showed greater distolateral sloping in TB whereas MCJ demonstrated more distomedial sloping in SB. RCJ and CMCJ had the most common features in the two breeds.

4. DISCUSSION:

The carpus has numerous anatomical features that have not been studied radiographically for any specific equine breed. The current comparison focused on the features of the three major articulations as well as the distal radial metaphysis which were considered as potential places for determining the carpal conformational soundness (Brauer et al. 1999). The findings revealed that there were similarities and differences in the carpal radiographic morphometries between Thoroughbred and Standardbred racehorses (Figure 3).

Differences between the two breeds were found in Ra.met-Prox.Mc3, MCJ-Dis.dor.C3, MCJ-Prox.Mc3 and Rf.C3-Dis.dor.C3 angles (Table 1). In contrast to the first parameter, the measurements in the other three parameters were obviously related to the distal carpal row at the levels of the middle carpal and carpometacarpal joints. The results showed that the angulations of the parameters were greater in Thoroughbreds than in Standardbred racehorses. Indeed, based on the orientation of the features of these angles in relation to the ground surface and longitudinal axis of the forelimb, these angulations indicated that the distal carpal row of SB declined more distomedially than in TB. These differences were represented in both the MCJ and CMCJ. However, in terms of the clinical and locomotor participation in the carpus, MCJ has a much greater range of movement than the CMCJ (Palmer 1986; Frandson et al. 2003; Dyce et al. 2010). Hence, it would be useful to specify which of those features caused the significant variations between the two breeds in the three parameters. Basically, there were four features selected to participate in the formation of the four parameters which represented the angulations between MCJ and CMCJ. From these four parameters, there was only one parameter that showed no significant difference between the breeds. That parameter was Dis.dor.C3-Prx.Mc3 and both of the bony features used to measure it were located on the CMCJ. Thus, it can be assumed that the reason for the significant variations which were related to the distal carpal row belonged to the two features on its proximal surfaces. These features both had a greater distomedial inclination in SB and were the middle carpal joint and the radial facet of the third carpal bone. Mechanically, the varied slope in the articular surfaces would probably influence loading distribution among the carpal bones in each breed.

This change in slope potentially introduces another level of complexity especially if the current finding correlates with previous studies on carpal morphology and fractures. The medial aspect of MCJ included an important articulation between the reciprocal shapes of the distomedial region of Cr and the proximomedial region of C3. Although the articulation was similar in the two breeds and received the highest axial loading in the carpus (Colahan et al. 1987; Bramlage et al. 1988; Palmer et al. 1994), their incidence of pathology varied considerably between the two breeds. According to Palmer (1986) and Pasquini et al. (1997), the proximomedial site of C3 was the most commonly injured region in SB whereas the distomedial part of Cr was the most frequently damaged site in TB. This different occurrence of pathology seems to be directly or indirectly associated with the varied sloping in the articular surfaces of MCJ which might consequently alter load concentration. If so, it might be then assumed that the more distomedial inclined surfaces of the middle carpal joint is more suitable to contain forces that are exerted in the symmetrical racing gaits such as in Standardbred trotting but not in Thoroughbreds which are racing at a high speed in an asymmetrical gait. However, measuring carpi from injured racehorses would be required for each breed in order to understand if there is indeed an association between pathological prevalence and middle carpal joint angulation in these breeds.

According to Oheida et al. (2016), Ra.met-Prx.Mc3 parameter was designed to identify the general carpal conformation and deformities such as valgus and varus. Unlike the carpal angle (Fretz 1980; Pharr and Fretz 1981) which is commonly used in clinics, the current angle was measured between the radius metaphysis and the proximal extremity of Mc3 (Oheida et al. 2016) instead of the longitudinal axes of the radius and Mc3. Measuring Ra.met-Prx.Mc3 angle in the current study exhibited a significantly greater angulation in Thoroughbred's carpi (185.51 ± 2.28) than in Standardbreds (183.75 ± 1.81). According to Auer (1999), the normal carpus should have a carpal angle of 180°. So, if this was the case, it means that the present measured carpi from both breeds had some degree of medial deviation or valgus. This would not be true because firstly the way of measuring the current angles was different from Fretz's method. Secondly, all the measured carpi were from normal TB and SB who were experienced racehorses with no history of any carpal damage through lengthy racing careers and hence regularly experienced enormous stress. Thus, the definition of valgus as a carpal deformity when its angle was more than 180° seems to be inaccurate and should be reconsidered at least for these groups of horses. The measurements illustrated a greater distolateral sloping of the parameter in TB than in SB. Such different degree of sloping in each group of these sound horses seems to be a specific protective response to the axial loading in order to avoid uneven concentration of the load through the carpal bony components. This would be supported by other studies which considered a carpal valgus of 185° as not only a normal (Weller et al. 2006a) but also a protective (McIlwraith et al. 2003) conformation against injuries in Thoroughbreds at least. The lower angulation in the

Standardbreds suggests that there may be different mechanical requirements for this angle associated with the Standardbred racing gaits. The varied angulation in Ra.met-Prx.Mc3 angle was most likely related to the radial metaphysis feature than to the proximal Mc3 feature. This part of the distal radius was considered as a contributory site for carpal deviation (Brauer et al. 1999) if excessive training occurred at young ages (Love et al. 2006). Hence, it could be assumed that the reason for the different slope in those breeds was probably a dynamic response of the radial metaphysis to the different loads and/or racing regime during early training. As the carpi of Thoroughbreds is likely to be exposed to more extreme forces during galloping especially during turning at high speed, the radial metaphysis might tend to be more affected and hence more sloped distolaterally than in Standardbreds. The extent to which the radial metaphysis might safely be inclined in sound TB racehorses is clearly not easy to detect. Perhaps the degree of the distolateral slope of the radial metaphysis in this study could present an important start. However, an excessive distolateral slope, up to the level of deformity, might be a reason for the higher susceptibility of the lateral aspect of RCJ to fracture compared with its medial aspect (Bramlage 1983; Palmer 1986; McIlwraith et al. 1987). Therefore, the Ra.met-Prx.Mc3 parameter appeared to represent a breed specific trait which may illustrate a general parameter for investigating the relationship between conformation and pathology and perhaps help in selecting horses that are more likely to stay sound in the carpus while racing.

In respect to the carpal morphological similarity, although most of the parameters showed no significant variation between the two breeds, almost all of their features presented a difference in one or more parameters. However, the only feature which showed no significant differences in any of its constructed parameters was the radiocarpal joint feature. The result might reflect the consistency of a common conformational trait in the two breeds along the distal extremity of the radius and the proximal articular surfaces of the proximal carpal row. Interestingly, this region was reported to be one of the most damaged places in the carpus and its incidence of fracture was significantly higher in TB than in SB (Palmer1986). The varied frequency of pathology in this particular region has been related to other factors such as different racing gait and/or speed (Bramlage 1983) rather than to the breed. In TB, during galloping and with the leading limb, an over-rotating and overextension might occur in the RCJ. This probably leads to increased contact between the margins of the bones and hence causes their fracture. In SB on the other hand, such a problematic mechanism would not happen due to the symmetrical racing gait in which both limbs were placed on the ground in sequence during trotting (Bramlage 1983). Thus the RCJ anatomical conformation would not be a factor in the differences in carpal pathologies in these breeds. Instead, its consistency should be considered as a common trait for both TB and SB racehorses.

In respect to the range of measurements between the highest and the lowest values of each parameter in all the horses, it was noted that there was a wide variation among the parameters. However, it was also noted that the smallest range of measurements was reported in Dis.dor.C3-Prx.Mc3 parameter which showed a range of 3.8°. As this parameter was designed to represent the conformation of only the CMCJ, the small range means that there was a high similarity among all the measured carpi in this region. Based on the fact that the CMCJ only contributes a small amount to the total carpal motion (Dyce et al. 2010), the current finding seems to be a reasonable result. The limited movement and the consistent conformation in CMCJ would be the main reasons for it being a rare place for carpal pathology (Palmer1986). In contrast, the largest range of measurements was seen in Ra.met-Rf.C3 angle which showed a range of 9.4°. The two features in this parameter have clinical and mechanical values for carpal soundness in racehorses. As discussed previously, since the radial metaphysis and the radial face of C3 were from the regions most affected by the diversity and strength of axial loading, their varied responses and consequently their varied angulations to that loading might have led to the wide range of measurements in this parameter. It can be suggested that the range of variation in each measured parameter among the horses depended on both the genetics and the location and forces which had been applied on its features during each horse's racing career.

5. CONCLUSION:

It can be seen that each of the two racehorse breeds had specific carpal conformational traits as well as common consistent features. The radiocarpal and the carpometacarpal joints had the most constant anatomical features which suggest that they are required for normal carpal function in both breeds. TB tended to have a more distolateral slope to their radial metaphysis whereas SB had a more distomedially inclined middle carpal joint. The varied sloping in carpal features might simply mean that there had been a different load distribution among the bony components. However, the current findings, whether similarities or differences, have not specifically investigated their association with different racing gaits, speeds or pathology. Therefore, further investigations are necessary to measure the carpal morphometry from untrained and injured horses. In untrained horses, the result would help to identify whether the reason of the variation was a breed effect or just a response to the different exercise. Finally, if the parameters showed considerable differences between sound and injured horses in each breed, then they might assist in identifying racehorses with ideal carpal conformation suited for racing as well as horses at increased risk of carpal damage.

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