THE 'PALMAR METRIC': A NEW MEASURE OF FOOT HEALTH

Tracy A. Turner, DVM, MS, Dipl.ACVS, John J. Craig, PhD, Monique F. Craig, BSCE, Matthew A. Burd, DVM, MS, and Amber Bowen.

Author's address: Turner: 16445 70th St. NE. Elk River, MN 55330 (Phone: 763-441-3797, Fax: 763-4413683, e-mail: **turner@anokaequine.com**),

Craig and Craig: P.O. Box 361, Creston, CA 93432 (Phone: 805-239-3505, Fax: 805-888-2855, e-mail: **john@eponatech.com**)

Burd and Bowen: Animal Science Department, California Polytechnic State University, One Grand Avenue, San Luis Obispo, California, USA 93401 (phone: 805-756-6110, e-mail: **mburd@calpoly.edu**)

TAKE HOME MESSAGE:. A new measure, the palmar-metric, which gives a measure of the volume of the concavity on the solar side of the equine coffin bone, may be helpful in measuring the health of the hoof and assessing the effect of environmental factors and age on the coffin bone.

INTRODUCTION: Radiographic assessment of the equine foot has been part of the veterinary evaluation for over 70 years. Multiple radiographic projections are used to thoroughly evaluate the bones of the digit so an opinion can be rendered regarding the presence of pathology, as well as, the nature and severity of that pathology[1]. In the equine digit, remodeling of the distal phalange is an important indicator of the overall health of the foot. Recently, the authors have investigated a new method based on the

LM radiograph of the equine digit which allows us to estimate the relative 'flatness' or 'cuppiness' of the solar surface of the pedal bone.

MATERIALS and METHODS: Three independent groups of horses were used as the basis of the studies reported in this paper. In total, 872 digital LM radiographs were analyzed in the results we report. Group #1 is a mixed breed group of 266 front feet, Group #2 consists of 278 Quarter Horse front feet, and Group #3 is 328 Thoroughbred yearling front feet. A new measure was developed, the "palmar-metric" which is based on measuring the area under a profile we call the 'palmar curve' which is evident in high quality LM radiographs of the equine digit (Figure 1). This is a calculated ratio, expressed as a percentage, of the area under the coffin bone relative to the area of a certain rectangle described by the bone (Figures 2, 3). Its value is dependent on the shape of the solar surface of the coffin bone. The more curve to the bone (solar concavity) the greater the ratio. Formulating this measure as a ratio of areas means that no scaling system is required for the radiograph, and also that our metric is not dependant on foot size. The value of the palmar metric ranges from zero (a totally flat pedal bone) up to values as high as 15.0 or more. Additionally, when scaled radiographs are available, a secondary and related computation can estimate the physical volume of the concavity of the solar aspect of the pedal bone in cubic centimeters (cc). The Metron equine hoof conformation software system[a] was used to make all of the measurements in the radiographs. This system makes use of scale markers and can compensate for the magnification inherent in radiographs[3].

Calculations. The palmar metric is a new quantitative measurement that can be made using a LM radiograph of the equine digit. In a high quality LM radiograph of the equine digit, one can see a contour that lies along the center of the solar surface of the P3 bone (Figure 1). For this study, LM radiographs of 872 normal horses and additionally 65 cadaver bones were used to develop this assessment. This contour is visible due to the increased density of the bone along that aspect due to mechanical needs of the DDFT that inserts there. This paper will refer to this curve as the ***palmar curve***. The method is to view the palmar curve as a mathematical function described relative to a coordinate system located at the distal tip of P3. To be precise, the origin of the reference system is located at the most distal point of the palmar curve. The Y-axis is oriented upwards, and the X-axis points back towards the caudal portion of the P3 bone. For a cadaver bone, its orientation when rested on a flat surface is "vertical" (Figure 3A). For in-vivo bones, one must make an estimation of the "P3 palmar angle" and then use it to define vertical (Figure 3B). The "palmar angle" is a popular radiographic measure currently in use by veterinarians when describing the orientation of the coffin bone within the hoof capsule. Several values could be computed from the palmar curve, for example, it's "straightness" ahead of the extensor process, and other measures. However, the measure found most useful has to do with the "area under the curve" for the portion of the palmar curve that lies distal to the perpendicular dropped from the extensor process (Figure 2). In general, young and/or healthy feet, will have more area under the curve. This measure gives a notion of how "cuppy" or how "flat" the solar surface of P3 is.

In one portion of our investigations, we used scaled radiographs of 65 cadaver bones to compute an estimate of the physical volume of the concavity of the solar side of

the P3 bone. This computation is related to our palmar-metric, but requires radiographs that can be accurately scaled for length measurements. On the 65 cadaver bones we carefully measured the actual volume of the palmar cup as shown in figure 4. We then radiographed the bones, traced the palmar-curve, and computed an estimate of the volume. The 65 bones used in the study had an average palmar cup volume of about 11 cc and our average error in estimating this volume from the LM radiograph was about 1 cc. Figure 5 shows a plot of our estimates, computed from the LM radiograph, compared to the actual, experimentally measured volume. The best fit line has a regression coefficient of 0.958 indicating that we can estimate the actual volume of the solar concavity from a LM radiograph quite well.

RESULTS: In our first mixed-breed study of 266 feet of known age (Group #1), the palmar-metric was calculated (figure 6). The red curve indicates the 3rd-order trend line of the data, and shows us the interesting result that the palmar-area metric, on average, decreases with age. The wide scatter of the data points indicates that many factors other than age must also affect the palmar metric. One could determine if a given individual lies above or below the value of the trend line for it's age as a means of rating the horse as having a below or above average P3 bone. The average palmar-metric for all horses in the study was 7.1.

In a second study (Group #2) we restricted ourselves to Quarter Horses and measured the palmar-metric for 278 radiographs for which the age of the horse at the time of the radiograph was known (figure 7). The red line is the 3rd order trend line of the data.

In a third study (Group #3), we restricted ourselves to Thoroughbred yearlings and measured the palmar-metric for 328 radiographs. A histogram of these values is shown in figure 8.

DISCUSSION: Radiographic assessment of the foot is extremely important and valuable information regarding the coffin bone within the hoof capsule can be assessed. We have introduced the palmar-metric as a means to assess the quality of the distal phalange in the horse.

In both Group #1 and Group #2 we see that the underlying trend is for the value of the palmar-metric to decline with age, but the scatter of the plots indicates that other factors play important roles. If our data were to fit the 'trend line' very tightly, it would be less interesting. In that case, it would be an accurate means of determining the age of a horse, and that is all. The fact the there is quite a large deviation in the data indicates factors other than age play an important role. Such factors may be genetic, or related to trimming and shoeing practices, or related to the horse's activity throughout its life. We hope to correlate other factors to the palmar-metric in future studies.

Our study using Group #3 shows that for a large group of same breed and equal age horses, there is still a distribution of the palmar-metric. Buyers of TB yearlings might be interested to know that a given horse already has a low palmar-metric at the age of one year, as this may be an indicator of early remodeling of the bone, or an indicator of a flat-footed or low-arch foot later in life.

In figure 9 we show data for a set of horses for which we have radiographs over a long term so that we can see how the palmar-metric changes for a given individual over

time. In all the horses for which we have such data, the palmar-metric declines as the horse ages. Without this fact, one could erroneously explain the data in figures 6 & 7 by claiming that horses with lower palmar-metric values live longer. The older horses with lower values of our metric were likely not born that way, but rather they became that way over their lifetime.

What is the explanation of the trend for the palmar-metric to decrease over the lifetime of the horse? We surmise that it is due to gradual demineralization of the bone. One can image that if the periphery of the bone demineralized, the depth of the solar concavity would decrease.

In figure 10 we present a scatter plot of the palmar-metric versus palmar angle for the 266 mixed breed feet. Palmar angle is a measure of the angulation of the P3 bone as it stands in the hoof. The red trend line hints at a worsening of our palmar-metric as the palmar angle becomes too small or too large. A large palmar angle, for example, can cause an increase of weight on the forward portion of P3 which, as a result, leads to more demineralization and hence a smaller palmar-metric over time. The peak of the trend line comes at a palmar angle of 3.4 degrees, which indicates that for the 266 feet of this study, on average the highest value of the palmar-metric was seen for feet with a palmar angle of 3.4 degrees. This could give credence to the notion that a palmar angle of about this magnitude is optimal in some sense. The Group #2 (Quarter Horse) data showed a similar shape, but with optimal palmar angle of around 1.5 degrees. There is a high amount of scatter in the data; indeed, just because the palmar angle was at a certain value in the radiograph used in the study, we do not know if that palmar angle was typical for

that foot over it's lifetime. Hence, we must be cautious in drawing conclusions from these data until further studies can be performed.

We believe that for any animal, once the pedal bone is mature, the palmar-metric will stay the same or decrease as the animal ages. We believe this metric is a useful means to capture the net effect of how the animal's lifestyle has impacted the quality of the distal phalange. It is hoped that a better understanding of how and why coffin bones remodel throughout the animal's lifetime, along with a way to measure this process from standard radiographs, will yield improvements in hoof care for the horse. For example, an interesting question is: what hoof care practices will minimize the loss of palmar-metric over time?

REFERENCES

1. Turner TA: How to subjectively and objectively examine the eguine foot, in *Proceedings.* Am Assoc Equine Pract 2006:52:531-537.
2. Merriam JG: How to radiographically assess the hoof capsule and related lameness problems, in *Proceedings.* Am Assoc Equine Pract 2006; 52:511-515.
3. Craig, J., Craig, M., and Weltner, T. Quantifying Conformation of the Equine Digit from Lateromedial Radiographs, in *Proceedings,* Assoc Equine Sports Med 2001; 21:20-25.

FOOTNOTES

[a] Metron, EponaTech, P.O. Box 361, Creston, CA 93432, USA

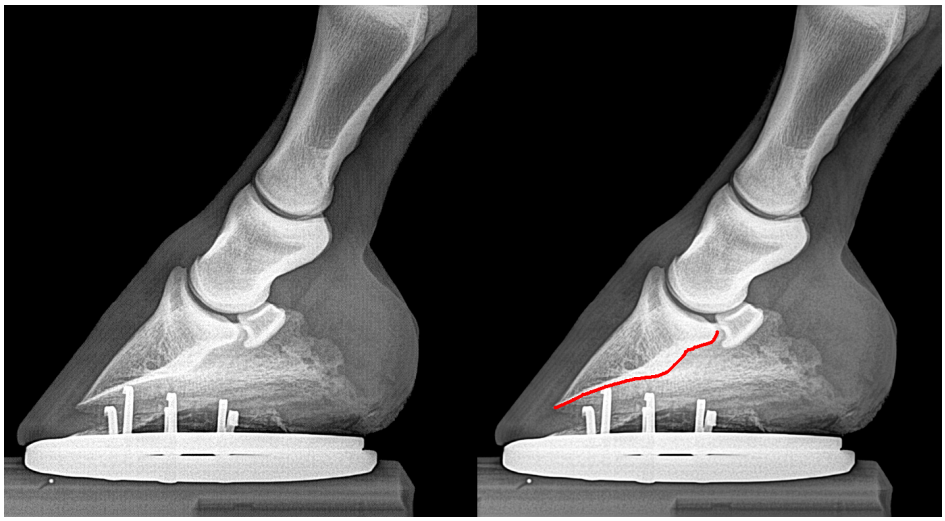

Figure 1: The 'palmar-curve' is evident in LM radiogrpahs. It is a bright contour which corresponds to midline of the palmar concavity of the pedal bone.

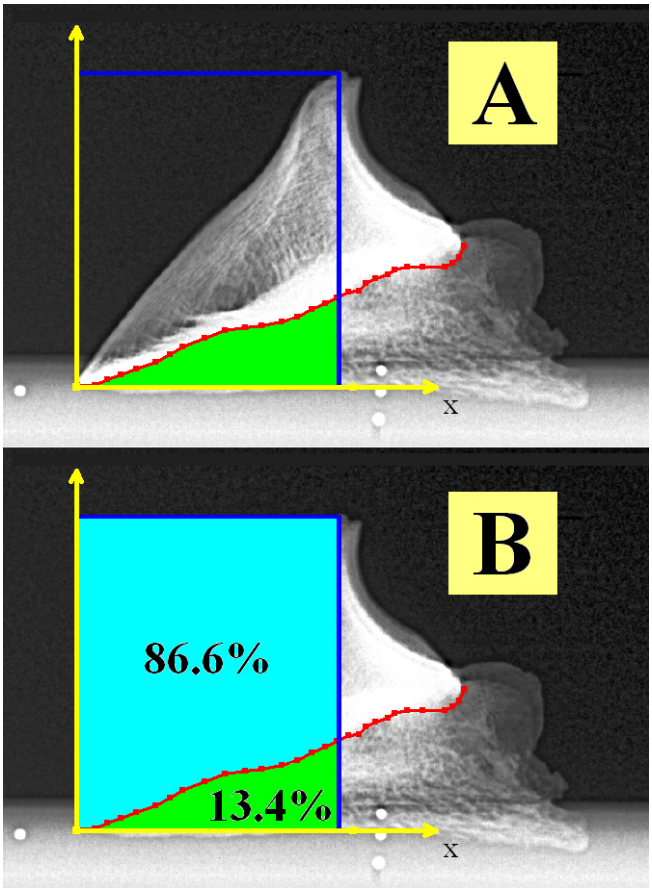

Figure 2: Our 'palmar-metric' is the number corresponding to the percentage of the area of the rectangle that is under the palmar-curve. For the pedal bone in this radiograph, the value of our metric is 13.4.

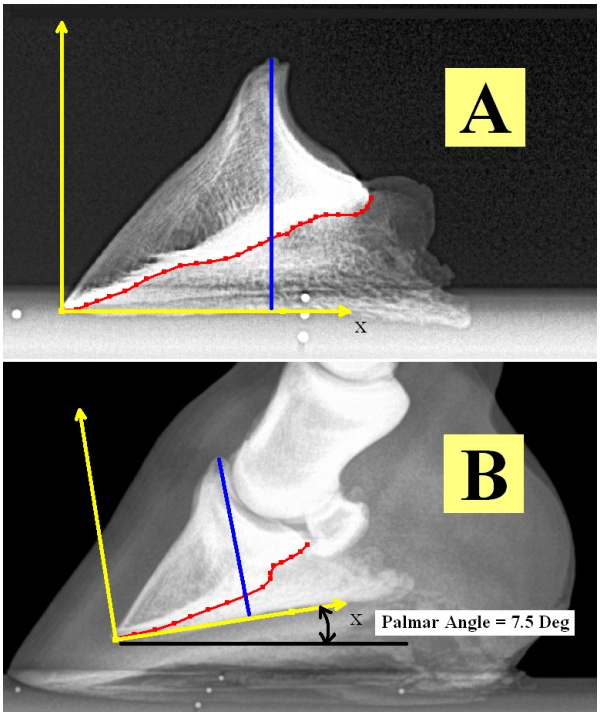

Figure 3: Application of the calculation to an in-vivo bone requires that the now familiar 'palmar angle' to be estimated.

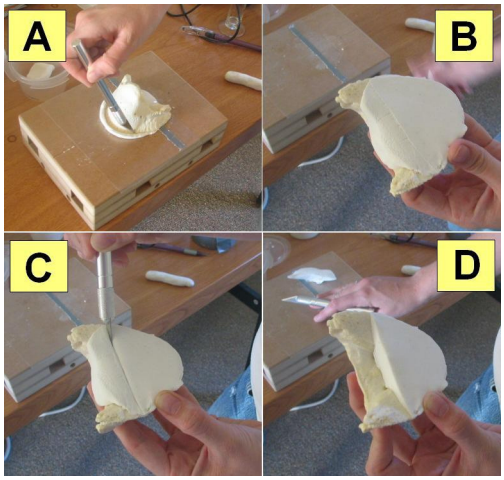

Figure 4: Experimentally measuring the volume of the solar cavity (ahead of the extensor process peak) for 65 cadaver bones. Putty was used to fill the concavity (A); the bone was placed with the extensor process above a marker so that a line was left in the putty (B) indicating where to trim (C). The putty (D) was removed and measured by water displacement to within 0.1 cc. The process was repeated 3 times for each bone and the results averaged.

.

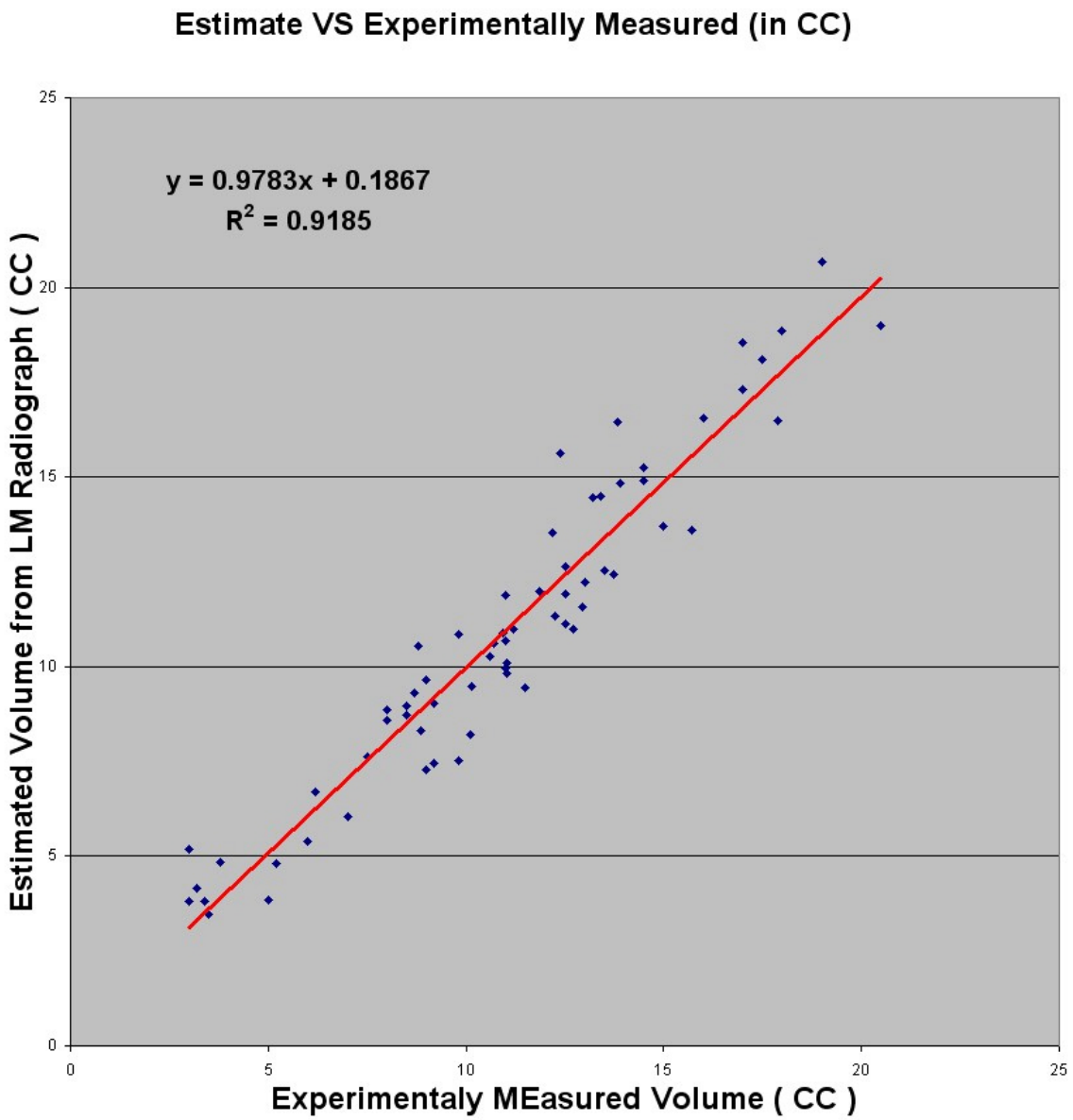

Figure 5: In a calculation related to our proposed metric, we can compute an estimate of the physical volume of the solar concavity when a scaled radiograph is available. This figure shows that our estimate of volume matches well the actual volume measured for a group of 65 cadaver bones

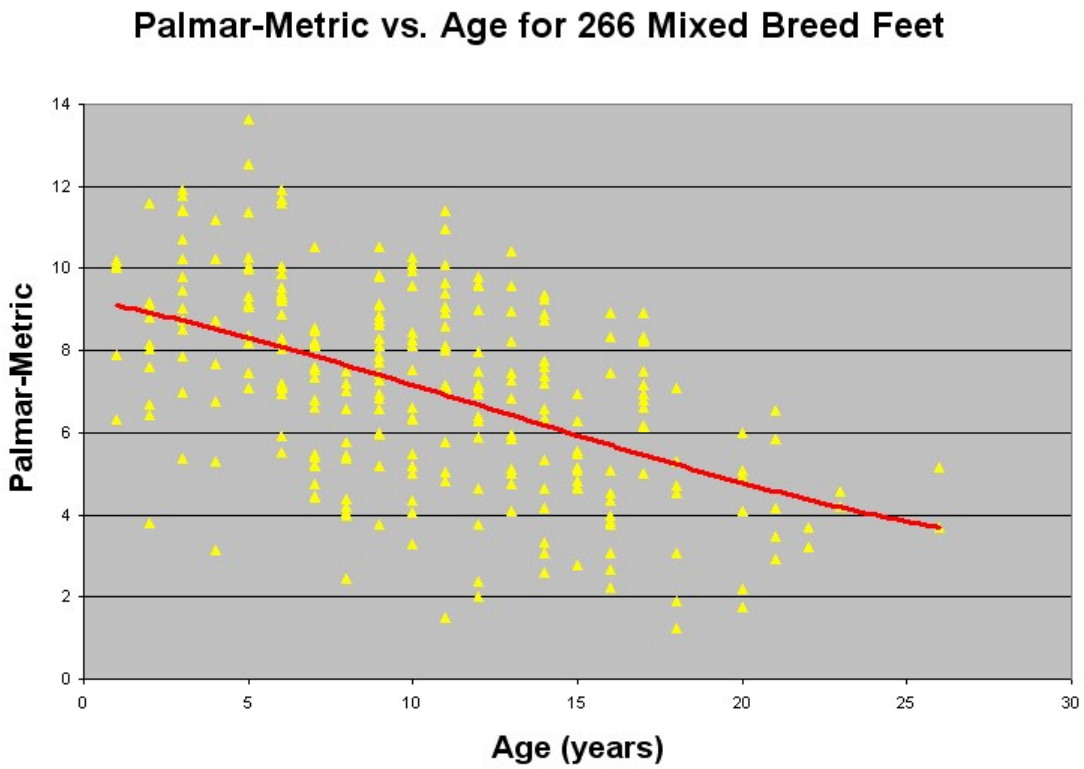

Figure 6: Results for group #1 (Mixed Breed group of 266 feet) showing the palmar-metric plotted versus the age of the animal

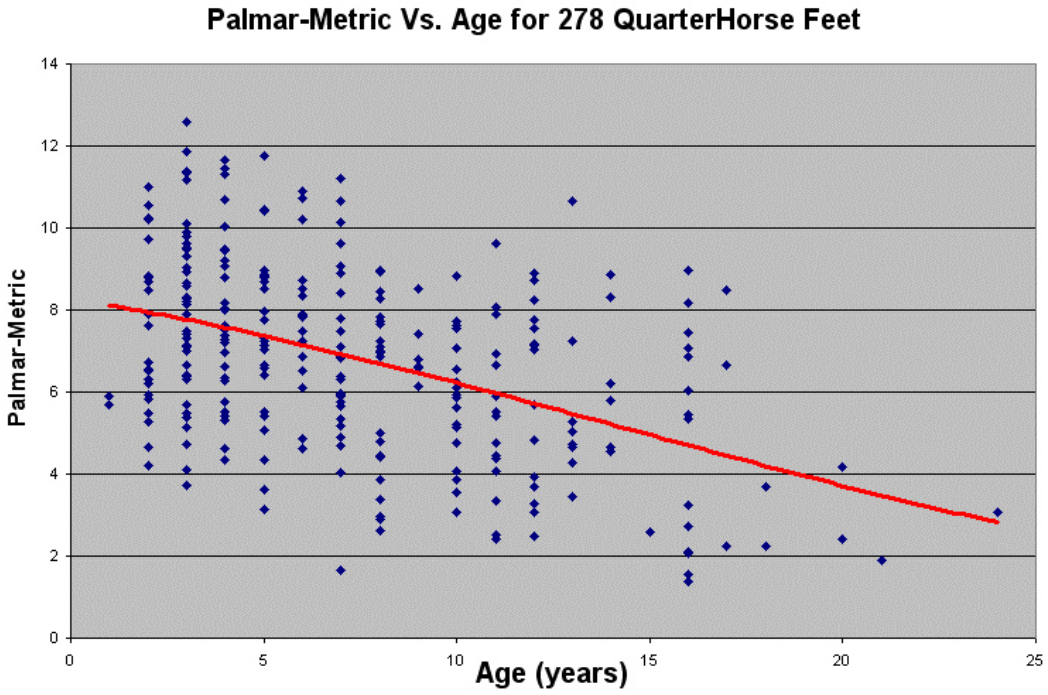

Figure 7: Group #2 (QuarterHorses) showing decline in palmar-metric with age.

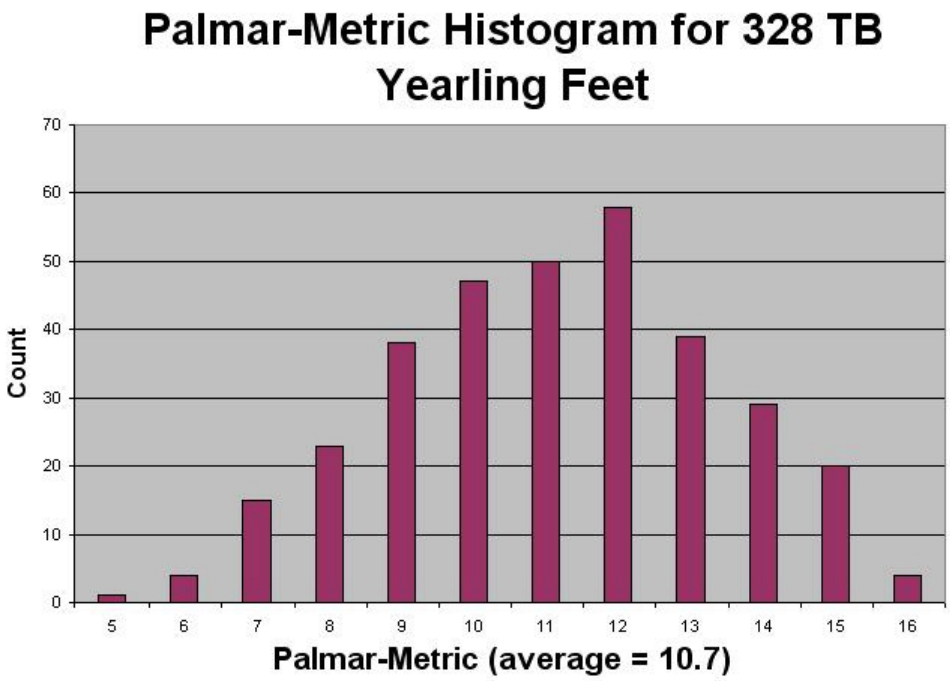

Figure 8: **Thoroughbred yearlings: This histogram shows the variation in the palmar-metric for a group of same breed and same age horses**.

Horse	Breed / Age 'After'	'Before'	'After'	Time Span
1	WB / 23	6.4	2.6	15.0 years
2	TB / 19	6.6	0.3	12.0 years
3	WB / 9	7.7	5.5	4.5 years
4	TB / 17	6.9	5.3	7.2 years
5	WB / 17	9.2	8.3	6.0 years
6	WB / 19	7.3	5.3	6.0 years

Figure 9: In a study of horses for which past radiographs of good quality were available, we found that in all cases, the "palmar area" metric decreased over time. The average rate of decrease for these horses was 0.33 per year.

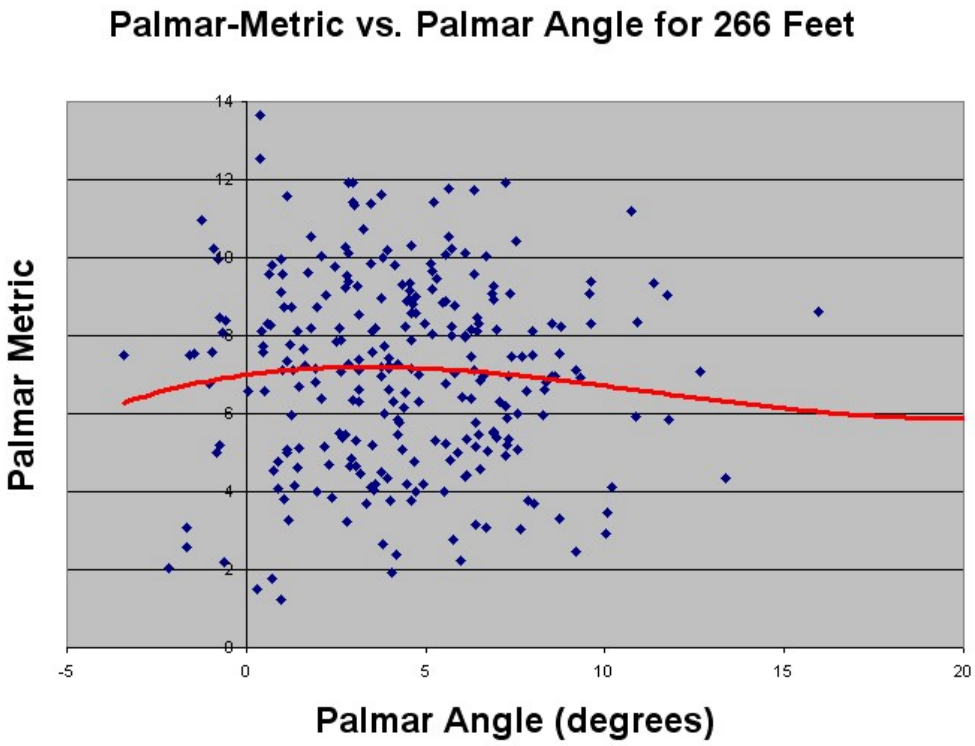

Figure 10: **The palmar-metric for Group #1 plotted against palmar-angle. The peak of the trend line occurs at palmar angle of 3.4 degrees.**