A Study of Growth Rates Around the Hoof Capsule Perimeter, Comparing Inter and Intra Hoof Regions

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Abstract

Reasons for performing this study: limited research has been carried out on hoof growth rates (HGR) around the hoof capsule. This study examines HGR in inter and intra hoof regions.

Objectives: To document and compare HGR at points around the hoof capsule; to compare hoof growth data within hooves, front to hind, between pairs; and assess any contribution of horse gender.

Methods: Over a three-month period HGR was measured in nine locations around the hoof capsule on all four feet of (n=10) shod horses. All horses were trimmed and shod by the author.

Results: The HGR range was 0.11mm/day to 0.25mm/day with a mean HGR of 0.16mm/day. The mean HGR was significantly higher in front feet compared to the mean HGR in the hinds ($P<0.05$). The mean HGR in front left feet was significantly greater than the front right mean HGR ($P<0.05$). Intra hoof results: the front lateral mean HGR was significantly greater than the medial mean HGR ($P<0.05$); the hind lateral to medial mean HGR showed no significant differences; the front *dorsum* mean HGR showed no statistical difference to the palmar mean HGR; the hind *dorsum* mean HGR was significantly higher than the plantar mean HGR ($P<0.001$). Mean HGR was significantly higher in mares than in geldings ($P<0.001$).

Conclusion: Horses feet grow at different rates in larger locational areas and there are differences amongst HGR between feet and horse gender.

The results show links with increased HGR in areas of greater impact upon the hoof capsule during dynamic phases.

Potential relevance: A greater understanding of differential hoof growth will lead to the application of more effective trimming protocols.

Declaration

I hereby declare that the work within this Fellowship thesis is my own. Any sources have been duly referenced.

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1. Introduction

"The hoof wall grows evenly distally to the coronary *epidermis*[1]*".* If this is true, why is it farriers rarely trim an even amount off the hoof capsules peripheral border? Whether hoof growth rate (HGR) occurs at different rates within the hoof capsule is unclear[2].

This study investigated the (HGR) around the hoof capsule, in nine locational points. It looked at: inter hoof relationships, intra hoof relationships and gender comparisons. The study was conducted over a three-month period, on (n=10) horses each shod on all four feet.

The horse's hoof is a continually growing structure throughout its life. The anatomy and physiology of the structure of horses' hooves are well documented but many of its functions are still poorly understood and its function is a neglected area of research.[3]

The hoof wall forms the largest portion of the hoof capsule; it can be classified into three layers:

1. *Stratum Externum*- outer layer referred to as the periople. This is produced from the papillae on the perioplic corium; it is a continuation of the *epidermis* of the skin. The periople scales off at a variable distance down the hoof wall to leave a thin flat layer of horn cells*, stratum tectorium*[4]
2. *Stratum Medium*- the main body of the hoof wall. It is produced at the coronary band from papillae on the coronary corium, where germinal

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[1] Baxter, Gary. M. (2011) *Adams and Stashak's Lameness in Horses.* Vol. sixth edition. Chichester, West Sussex: (Wiley-Blackwell publishing ltd).

[2] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry

[2] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry
biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine veterinary Journal.* 26, 51-57.

[3] Reilly, J. D. (1995)"No hoof no horse." *Equine veterinary Journal*. 27 do you need page numbers here or is it the whole of volume 27?

[4] Reilly, J.D. *The hoof capsule.* (2006) Vol. 2, in *Corrective farriery*, a text book of remedial horseshoeing, edited by Curtis, S. 344-361. Newmarket Farriery Consultancy

cells called keratinocytes (or keratin producing cells) mature and keratinise continually adding to the proximal hoof wall.[5] These cells produce the tubular and intertubular horn. This horn descends distally to the ground surface of the hoof capsule. The hoof wall appears to be reinforced by the tubules but it is the intertubular horn that accounts for most of its mechanical strength, rigidity and fracture resistance.[6] The tubules of the hoof are arranged in four distinct zones based on density of tubules in the intertubular horn.[7] These zones decrease in tubule density towards the internal lamellar layer.

3. *Stratum Internum*- the inner hoof wall. It consists of primary and secondary epidermal lamellar. It is produced on the shoulder of the coronary groove by papillae on the coronary corium. The primary function of the lamellar horn is to suspend the distal phalanx within the hoof capsule.[8]

Anecdotal Observations:

When trimming and shoeing horses' hooves, they rarely seemed to grow at even rates. This was noticed when examining hoof trimmings during regular trimming cycles of four to eight weeks. It was rare to have an even trim around all four feet on any horse. The hoof trimmings showed that the hoof wall grew at a faster rate laterally than medially and a faster toe to heel ratio was observed. From these observations it would seem that horses feet grow unlevel, over a normal shoeing period. Studies have shown that up to 95% of horses have some form of foot imbalance, which predispose them to injury.[9] Foot balance is still an area that differs in opinion amongst farriers and veterinary surgeons alike;

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[5] Pollitt, C.C. (1998) "The anatomy and physiology of the hoof wall". *Equine veterinary education*. 10, 318-325.

[6] Pollitt 1998

[7] Reilly, J.D. Cottrell, D.F. Martin, R.F. and Cuddesford, D. (1996) "Tubule density in equine hoof horn." *Biometics.* 4, 23-35.

[8] Pollitt, 1998

[9] Williams, G. and Deacon, M. (1999) *No Foot No Horse*. Addington, Buckingham: (Kenilworth Press Ltd). Page 11.

different trimming methods are used amongst practitioners; trimming to the long axis, to the solar plane, foot mapping, trimming equal wall length and four point trimming being a few examples of recognised farriery methods.

Literature review:

Limited research has been carried out in this area to date and papers that have been published have concentrated on HGR at the *dorsum* region only; the literature was examined and is summarised here concentrating on aspects relevant to the themes of this thesis.

Previous studies confirm HGR at the *dorsum*, with HGR ranging between 0.16mm/day[10] to 0.25-0.38mm/day.[11] The difference in these findings could be influenced by: location, time, gender, nutrition, age, height and the breed types of the horses studied. Previous research has been carried out over different time periods that range from eleven weeks (Florence and McDonnell[12]) to twelve months (Frackowiak and Komosa[13]). The studies conducted over twelve month periods have shown seasonal differences in HGR but this will not be examined here, as the time scale of the study was three-months.

The majority of horses in work within the United Kingdom are shod. Little is known about HGR in shod horses to date. Although Reilly *et al*[14] showed photographic evidence of shod feet in their study they gave no mention of shoeing in their methodology. Measuring HGR on shod feet may have impacted results, through applying a semi rigid structure to the horses' foot, thus affecting its natural function.

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[10] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine veterinary Journal.* 26, 51-57.

[11] Butler, K.D. and Hintz, H.F. (1977) "Effect of level of feed intake and gelatin supplementation on growth and quality of hoofs of ponies." *Animal Science*. 44, 257-261.

[12] Florence, L. and McDonnell, S. (2006) "Hoof growth and wear of semi-feral ponies during an annual summer 'self trimming' period." *Equine veterinary Journal.* 38, 642-645.

[13] Frackowiak, H. and Komosa, M. (2006) *"The dynamics of hoof growth of the primitive Konik horses (equus caballus gmelini Ant.) in an anual cycle." Biological Rhythym Research*. 37(3), 223-232.

[14] Reilly, J.D. Hopegood, L. Gould, L. and Devismes, L. (1998) "Effect of a supplementry dietry evening primrose oil mixture on hoof growth, hoof growth rate and hoof lipid fractions in horses: a controlled and blinded trial." *Equine veterinary Jounal.* 26, 58-65

Studies have shown significant differences in HGR between front and hind feet. Butler and Hintz[15] found that hind feet grew at a faster rate by 7 to 18% . Florence and McDonnell[16] found a front foot mean HGR of 0.34mm/day, a hind mean of 0.32mm/day, with a significant difference of front feet growing at a faster rate than the hinds, ($P<0.05$).

There are limited studies showing differences between left and right foot HGR. Reilly et al[17] found no significant difference between left and right feet HGR. Studies have been carried out on laterality in foals and horses finding evidence of horses being 'left handed' or 'right handed' with a higher percentage showing right sided bias[18]. Gray[19] found aproximately 75% of horses studied showed a right handed preference, with the right hind being the dominant drive and the left fore being the prefered lead leg. Van Heel[20] looked at development of uneven front feet in foals and its relationship with laterality, finding 50% of foals developed uneven front feet through uneven weight distribution, due to a significant preference of limb. To date it has not been examined if HGR has any relationship with laterality. Studies have shown significant differences in foot size in front feet , the left being larger in 70% of the horses studied.[21]

Limited research has been performed on HGR at the medial and lateral sites of the hoof wall; the only study that set out to look at different locational points was performed by Frackowiak and Komosa.[22] They described measuring

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[15] Butler, K.D. and Hintz, H.F. (1977) "Effect of level of feed intake and gelatin supplementation on growth and quality of hoofs of ponies." *Animal Science*. 44, 257-261.

[16] Florence, L. and McDonnell, S. (2006) "Hoof growth and wear of semi-feral ponies during an annual summer 'self trimming' period." *Equine veterinary Journal.* 38, 642-645.

[17] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine veterinary Journal.* 26, 51-57.

[18] Curtis, S.J. (2012) "The effect of laterality on shoeing and trimming." *American Farriers Journal.*

[19] Gray, E. (1989)"Equine Asymmetrical dexterity, or the Preferred lead syndrome." *American Farriers Journal*. Vol 15, 26-31.

[20] Van Heel, M.C.V. Van Dierendonck, M.C. Kroekenstoel, A.M. Van Weeren, P.R and Back, W. (2006) "Uneven feet in a foal may develop as a consequence of lateral grazing behaviour induced by conformational traits." *Equine veterinary Journal.* 38, 646-651.

[21] Kummer, M. H. Geyer, I. Imboden, Auer, J. and Lischer, C. (2006) "The effect of hoof trimming on radiographic measurements of the front feet of normal warmblood horses." *The veterinary journal.* 172, 58-66.

[22] Frackowiak, H. and Komosa, M. (2006) *"The dynamics of hoof growth of the primitive Konik horses (equus caballus gmelini Ant.) in an anual cycle." Biological Rhythym Research*. 37(3), 223-232.

at toe quarters and both medial and lateral heels. However, they published no results to show any findings of HGR at these locations. Studies have confirmed statistical differences in horn tubule density in medial and lateral quarters of front feet, showing higher density in the medial aspect of the hoof ($p<0.05$), due to load differences.[23] It would seem unclear if tubule density differences have an effect on HGR.

Frackowiak and Komosa[24] also looked at the HGR in mares and stallions, finding a higher growth rate in juvenile mares within the study. These findings contradict, Butler and Hintz[25] who found no significant difference in gender.

[23] Lancaster, L.S. Bowker, R.M. and Mauer, W.A (1998) "Equine hoof wall tubule density and morphology." *Journal of veterinary medical science*, 2013, 773-778.
Pollitt, C C. "The anatomy and physiology of the hoof wall." *Equine veterinary education.* 10, 318-325.

[24] Frackowiak & Komosa, 2006

[25] Butler, K.D. and Hintz, H.F. (1977) "Effect of level of feed intake and gelatin supplementation on growth and quality of hoofs of ponies." *Animal Science*. 44, 257-261.

Objectives of Study**:**

The aim of this study was to document HGR in nine locational points around the hoof capsule, of (n=10) shod horses on all four feet over a three-month time period. The objectives were:

1) To measure HGR around the hoof capsule.

2) To compare inter hoof relationships (opposing hooves left to right and front to back).

3) To compare intra hoof relationships (within hoof capsule, medio/lateral and dorso/palmar/plantar).

4) To compare HGR in mares and geldings.

The Hypotheses were:

1) A horse's hoof does not grow at a parallel rate around the hoof capsule.

2) A horse's hind feet grow at a faster rate than the front feet.

3) A horse's hoof grows at the same rate on left and right feet.

4) A horse's hoof grows at a higher rate laterally than medially.

5) A horse's hoof grows at a higher rate at the *dorsum* compared to the heel.

6) A mare's hoof grows at a faster rate than a gelding's hoof.

2. Materials and Methodology

Population

A convenient selection group of (n=10) horses was chosen. The owners of the horses used in the study granted written consent, (Appendix I). The horses were all of sound limb and hoof at the start of the study. They were shod and trimmed exclusively by the author for the duration of the study.

The population was a mixed selection of horses in regular work. The group consisted of (n=5) mares and (n=5) geldings representing varied heights, ages and breeds.

The first (n=3) horses that were used were Lusitanos. They were all kept in the same environment, work regime and diet. These (n=3) horses were used as a pilot study, to test methodology. The data was collected between 19/05/2015 and 11/08/2015. Once the methodology was tested and found to be satisfactory, it was then repeated on the next (n=7) horses.

The succeeding (n=7) horses were kept in three different locations and were of varied breeds, kept in different environments and on varied diets. The data was collected between 17/02/2016 and 13/05/2016.

Each individual horse had a written profile that included: age, breed, height, and hoof size (width, from widest point to widest point, length, from centre of toe to point of lateral heel, heel width, point of heel to point of heel. These three measurements combined equalled hoof size). They were given individual numbers in order to maintain objectivity and anonymity (Appendix II). All feet used in the study were trimmed by the author to the individual requirements of the equine. After static conformation and dynamic gait assessments, a trimming protocol was determined for each individual. All feet were assessed in three planes: medio/lateral, hoof pastern axis and solar

symmetry[26]. All feet were trimmed after using these methods of assessment. The feet were trimmed to the long axis using the T-square theory[27]. The horses were shod in concave fullered shoes; the front feet shod with a toe clip and the hind feet shod with quarter clips.

Foot Marking

All four feet on each horse were used within the study. Each foot was marked with pen on nine points around the capsule. The hooves were visually bisected into areas of: *Dorsum* (centre of midline), toe Quarters (medial and lateral), quarters (medial and lateral), heel quarters (medial and lateral), and heels (medial and lateral). The heel markers were located at the most caudal point of the capsule within a 10mm margin of the heel. All markers were checked by the author to ensure they were consistent on each foot.

When the markers were in the final placements a Dremel tool, with a 3mm milling tool was used to mark the horny wall (Figure 1). The 3mm tool was used for its visibility when measuring throughout the study. Each marker was drilled to approximately 2mm deep into the horny wall. This was with the exception of one horse that did not tolerate the Dremel noise; on this horse a small hand crafted point was made, then heated up and burnt into the wall to give the locational markers. Ethical considerations were taken into account in order to ensure that the markers or measurements would not damage the hoof capsule, or cause any harm to the horse (Figure 2).

[26] Curtis, S.J. (1999) *Farriery - foal to Racehorse.* Newmarket, Suffolk: (R&W Publications Newmarket Ltd).

[27] Williams, G. and Deacon, M. (1999) *No Foot No Horse*. Addington, Buckingham: (Kenilworth Press Ltd). Page 37.

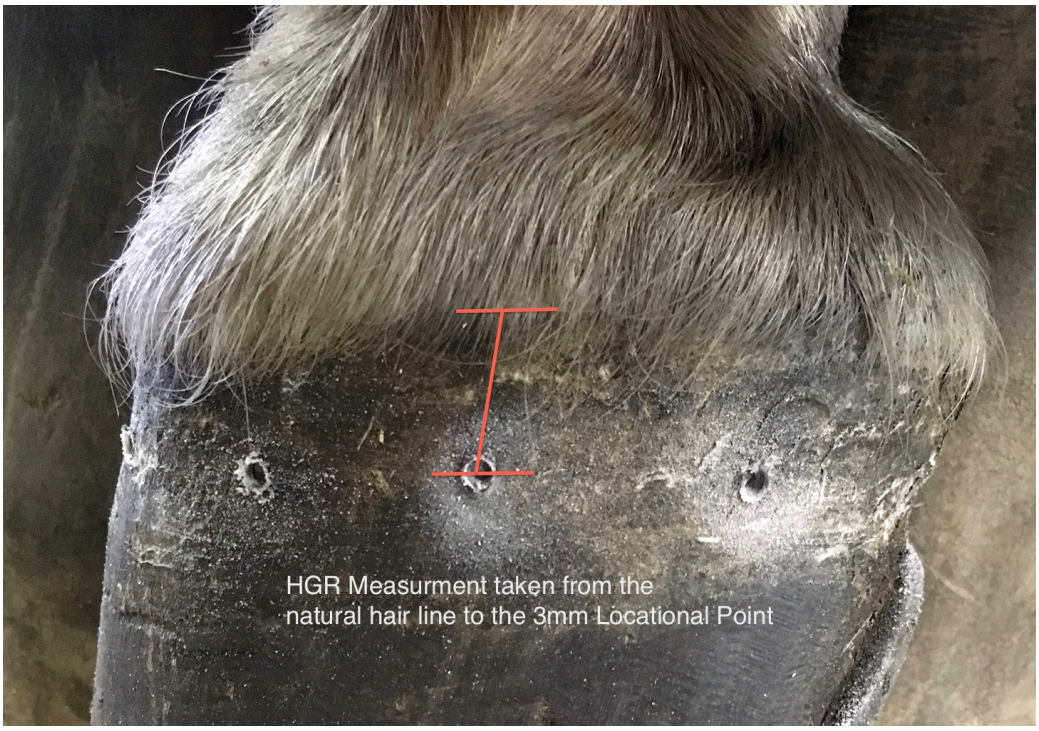

Figure 1. Locational points marked into hoof capsule, showing; angle and distance measured.

Figure 2. Hoof at the end of the study, showing that the markers did not damage the hoof wall.

Measurement and Data Collection

A base measurement was taken from the coronary hairline around the coronary border of the hoof capsule to the centre of the marker in the capsule (Figure 3), following the method used by Reilly et al.[28] The feet were individually measured non-weight bearing on a foot stand. This measurement was to be the zero measurement, a baseline used to commence the study. This base measurement was calculated using free logix digital callipers[1] in mm to a tolerance of 0.01mm. The callipers were held in alignment with the angle of the hoof wall in each of the locational points (Figure 1). The author carried out each of these measurements. Each measurement was called to an assistant who recorded it on a data collection sheet (Appendix III). The data was recorded to two decimal places. Each marker was measured on each foot on each horse. These measurements were repeated at approximately six-week intervals over a period of approximately three-months. This time period was chosen as to carry out a preliminary study. It was anticipated that the heel markers would possibly grow out within this time frame. To continue over a longer period of time the methods would have to be repeated.

[28] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine vetinary Journal.* 26, 51-57.

Figure 3. Measuring from coronary hairline to centre of marker, using digital callipers

The collected data was transferred to an Excel[2] spreadsheet showing the date the measurement was taken and measurements from each point measured over the three-month period. From these figures the mean HGR could be worked out by taking the overall measurement from the three-month period and dividing it by the days measured. This gave a mm/day mean HGR for each of the locational points.

The data from each of the individual horses was added together in each of the location points. These final figures were divided by the number of horses within this study (n=10). These figures were used to generate the mean HGR for each locational point from the study. The data collected from the medial and lateral heel and heel quarters were added together and divided by four to give mean heel HGR. The *dorsum* and both medial and lateral toe quarters were added together and divided by three to give the mean *dorsum* HGR. The four lateral points were added together as were the medial four points and divided by

four to give both lateral mean HGR and medial mean HGR. These calculations were performed for each horse on each hoof, then added together and divided by the total horses within this study (n=10). All data was then analysed.

Statistical Analysis

Minitab[3] software was used to analyse the data. The areas that were tested were: mean hoof growth rate (HGR) around the capsule, using an Anderson-Darling normality test. Inter foot HGR means were tested against each other left/right and front/hind. Intra hoof HGR means were tested; (measurement of the four medial points tested against the four lateral points) and mean *dorsum* against mean heel using paired t- tests. Pearson's correlation compared HGR and age and a paired *t*-test compared gender. Tests with confidence levels of 95% ($p<0.05$) were considered significant.

3. Results

All data was tested for normal distribution using Anderson-Darling (Figure 3).

A summary of results is shown in (Table 2)

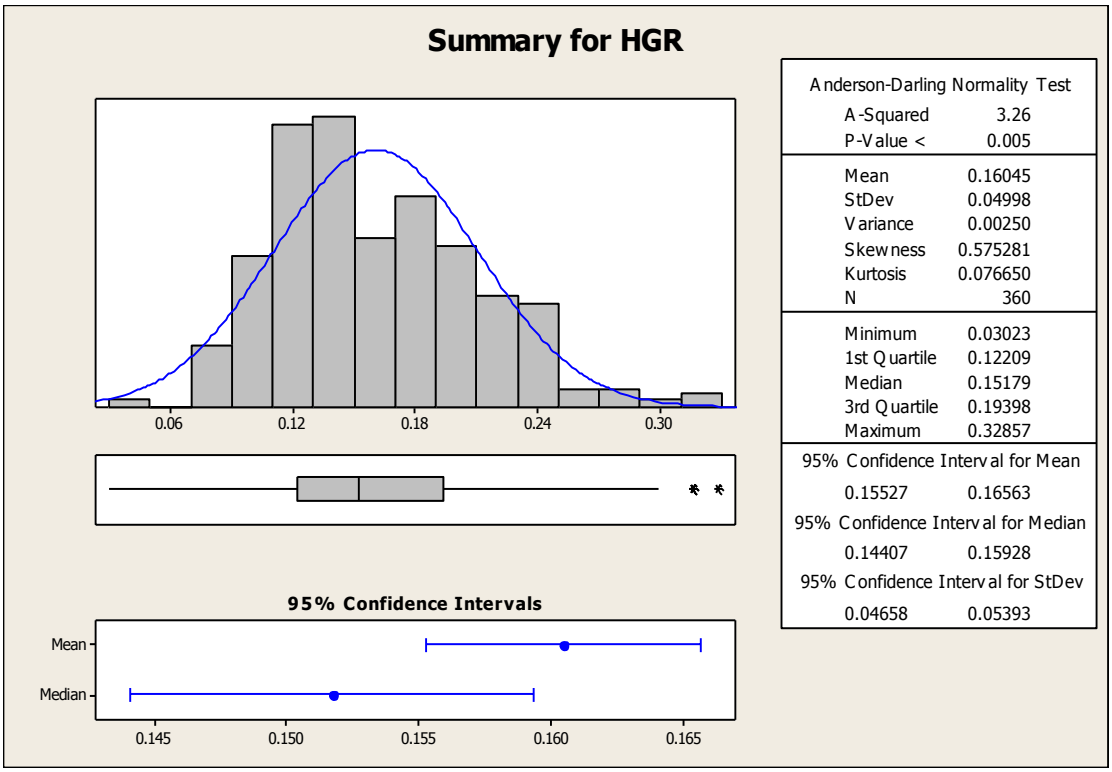

Figure 3: *Anderson-Darling normality test, summary for mean HGR.*

Table 2: Summary of results.

Horse No	Gender	Age Years	LF HGR mm/day	RF HGR mm/day	LH HGR mm/day	RH HGR mm/day	Total HGR mm/day
1	Gelding	19	0.15	0.11	0.13	0.14	0.13
2	Mare	6	0.22	0.23	0.19	0.20	0.21
3	Gelding	8	0.15	0.12	0.14	0.13	0.14
4	Gelding	13	0.12	0.12	0.14	0.14	0.13
5	Mare	20	0.13	0.13	0.09	0.11	0.11
6	Gelding	19	0.13	0.15	0.10	0.11	0.12
7	Gelding	19	0.27	0.25	0.23	0.24	0.25
8	Mare	8	0.18	0.14	0.19	0.15	0.17
9	Mare	11	0.15	0.15	0.15	0.15	0.15
10	Mare	14	0.18	0.20	0.20	0.20	0.20
	Mean	13.7	0.17	0.16	0.16	0.16	0.16

The means were calculated for each horse showing: age in years, left front HGR, right front HGR, left hind HGR, right hind HGR and total HGR. (Table 2) .The range could be calculated from this data.

The mean HGR from this study was 0.16 mm/day. The Anderson-Darling test showed a normal distribution of data within the study (Figure 3); the range was 0.11mm/day to 0.25mm/day.

The mean age was 13.7 years old within this study. The range was 6 to 20 years old.

The means from each locational point on the (n=10) horses' were tested using a One-way ANOVA test, there was an absolute difference in the means in the locational points (Figure 4), but there was no significant difference found between the means in the locational points (P >0.05) (Appendix IV) (Figure 5).

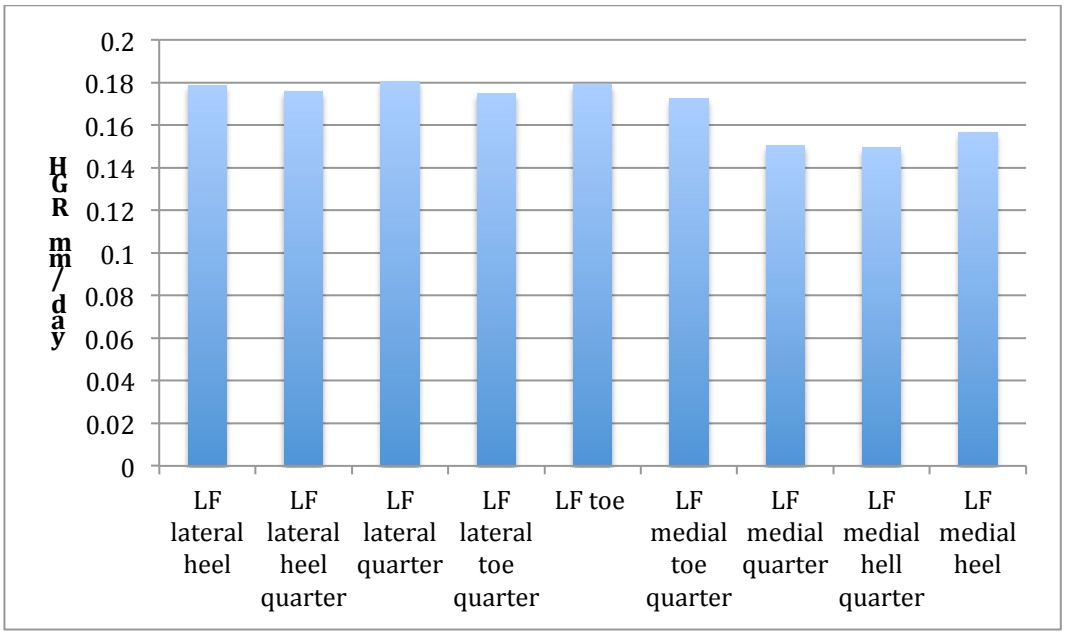

Figure 4: Left front mean HGR's in locational points.

Inter foot results

The front feet mean HGR was 0.164mm/day and the hind feet mean HGR was 0.156mm/day, indicating the front feet HGR's were significantly greater than the hinds; ($P < 0.05$) (Appendix IV) (Figure 6). The front feet were compared left to right: the left fore mean HGR was 0.168mm/day and significantly greater than the right fore mean HGR of; 0.159mm/day, ($P<0.05$) (Appendix IV) (Figure 7). The hind feet were compared in the same way: the left hind mean HGR was 0.155mm/day, and the right hind mean HGR was 0.157mm/day, showing no significant difference, ($P>0.05$) (Appendix IV) (Figure 8).

Intra foot results

The front feet were compared laterally to medially, the combined lateral mean (lateral toe quarter, lateral quarter, lateral heel quarter, lateral heel) was divided by four to give a result of 0.168mm/day and the combined medial mean (medial toe quarter, medial quarter, medial heel quarter, medial heel) was divided by four to give a result of 0.158mm/day, the lateral mean was significantly greater than the medial ($P<0.05$) (Appendix IV) (Figure 9). The hind feet were compared laterally to medially in the same manner, the combined hind lateral mean was divided by four to give a result of 0.150mm/day and the combined medial mean was divided by four to give a result of 0.157mm/day, the lateral and medial mean had no significant difference ($P>0.05$) (Appendix IV) (Figure 10).

The front feet were compared dorsum to heel, the dorsum mean HGR in the front feet was 0.168mm/day, the heel mean HGR was 0.162mm/day, no

significant difference was found (P>0.05) (Appendix IV) (Figure 11). The hind feet were compared *dorsum* to heel, the hind *dorsum* mean HGR was 0.169mm/day, and the heel mean HGR was 0.154mm/day. The hind *dorsum* mean HGR was greater than the heel mean HGR, being highly significant (P<0.001). (Appendix IV) (Figure 12).

Gender results

The mean HGR for mares was tested against the mean HGR for geldings, the mares mean was 0.166mm/day; the geldings' mean was 0.153mm/day. The mares mean HGR was greater than the geldings mean HGR, it was found to be a highly significant difference (P<0.001) (Appendix IV) (Figure 13).

4. Discussion

The extensive data collected from this study (n=360) enabled analyses of many factors of HGR in horses. Throughout the study (n=360) points of data were collected and comprised of measurements in each of the nine locational points, on all four feet, of all (n=10) horses. The measurements from each horse were divided by the days measured to give a reading in mm/day; this data divided by the horses within the study (n=10) gave a mean HGR within this study of 0.16 mm/day. This figure corroborates the findings of Reilly et al[29], which examined data collected over a similar time frame. Due to the mean being derived from the nine locational points the mean HGR in this study was calculated in a unique way, which has not been used in any previous study. This represents a more accurate reading of the overall hoof capsule HGR. The varied HGR within the population could be due to many factors: environment, age, breed type, nutrition, hoof size and height.

The first hypothesis showed that within the data tested, there were absolute differences in the locational points. However, upon statistical testing it was found that there was no evidence of the hoof growing at different rates in the locational points ($P>0.05$). These findings void the first hypothesis tested, creating a null hypothesis.

The second hypothesis was tested statistically using a paired t-test. This gave statistically significant evidence in favour of the front feet growing faster than the hind feet ($P<0.05$), providing a null hypothesis. These results reflect the same findings as Florence and McDonnell,[30] but contradict Butler and Hintz[31],who found the reverse was shown. These results may be due to the load differentials placed on the front to hind feet, the front feet taking approximately

[29] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine vetinary Journal.* 26, 51-57.
[30] Florence, L. and McDonnell, S. (2006) "Hoof growth and wear of semi-feral ponies during an annual summer 'self trimming' period." *Equine veterinary Journal.* 38, 642-645.
[31] Butler, K.D. and Hintz, H.F. (1977) "Effect of level of feed intake and gelatin supplementation on growth and quality of hoofs of ponies." *Animal Science*. 44, 257-261.

60% of the body weight and the hind feet taking approximately 40% of the body weight. This load difference will have an effect on the impact upon the hoof capsules of the front feet, when the horse is dynamic. The higher impact may have an involvement in the increased HGR. Due to a lack of research it is currently unclear whether load affects HGR.

The third hypothesis showed statistical significance in favour of left front feet growing at a faster rate than the right ($P<0.05$). This confirmed the hypothesis using data from the front feet. But contradicts the findings of Reilly et al[32], the difference with these findings may be due to the whole capsule being used to acquire data, not just in the *dorsum,* or the population had a more varied laterality. The same process was repeated for hind feet and showed no statistical significance ($P>0.05$) providing a null hypothesis, corroborating with Reilly et al [33]. These results may be linked with laterality in the fore feet; As stated by Curtis[34] and Gray[35] where horses show a higher percentage of having a right side bias, when a horse has a right side bias it will lead with the opposing leg, the left leg. The findings within this study could show a link in weight distribution and loading both statically and dynamically. It is possible that the changes in HGR occur because of this; however this would need further study. The results may also have some relevance with studies showing asymmetry in front feet, in 70% of the horses studied the left front foot was found to be larger, Kummer et al.[36] This is not conclusive and would need further research to provide a deeper understanding of the subject.

The fourth hypothesis tested the collected data of the lateral and medial HGR, showing a significant difference of a higher HGR laterally ($P<0.05$). This confirmed that the hypothesis was valid when using data collected from the front

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[32] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine veterinary Journal.* 26, 51-57.
[33] Reilly et al (1998)
[34] Curtis, S.J. (2012) "The effect of laterality on shoeing and trimming." *American Farriers Journal*.
[35] Gray, E. (1989)"Equine Asymmetrical dexterity, or the Preferred lead syndrome." *American Farriers Journal*. Vol 15, 26-31

[36] Kummer, M. H. Geyer, I. Imboden, Auer, J. and Lischer, C. (2006) "The effect of hoof trimming on radiographic measurements of the front feet of normal warmblood horses." *The veterinary journal.* 172, 58-66.

feet. The same was tested in the hind feet showing no statistical difference (P>0.05). When using data collected from the hind feet it presented a null hypothesis. The difference between lateral and medial growth in the fore feet is noticeable when trimming feet to the long axis. The front feet difference may have a link with the tubule density difference shown in medial and lateral quarters. A higher tubule density is shown in the medial quarter[37], this is due to the load placed upon the hoof capsule when static; therefore weight distribution being greater down the medial aspect of the limb. This is due to the anatomical structure of the horse's fore limbs. It is noticed that horses land firstly on the lateral aspect of the front foot then on to the medial aspect. The capsule is fully load bearing when the horse's body weight is over the weight-bearing limb, suggesting greater load on the medial aspect in the stance phase. During the break over phase the horse will break over towards the lateral toe. This greater force on the lateral aspect of the hoof, when the horse is in the dynamic phase may have involvement in changes in HGR on the lateral aspect. It is possible it could be reduced load on the lateral aspect in the stance phase.

The fifth hypothesis was tested, using a paired t-test, showing no statistical difference between the two HGR means of the *dorsum* and palmar aspects, within the front feet (P>0.05). This evidence showed a null hypothesis when applied to front feet. The same was tested in the hind feet showing a highly significant result in the *dorsum* growing at a higher rate than the plantar aspect (P<0.001), confirming the hypothesis within the hind feet. These inconsistent results are likely to be due to load forces within the hoof capsule. It is noticed that the front feet land more laterally to medially than dorsally/palmarly. The function of the hind limbs is to drive the horse forward, with the hind toe pushing into the ground for purchase. This movement puts the dorsal aspect of the hoof capsule under greater load. These factors may have involvement with the differences in HGR found.

[37] Lancaster, L.S. Bowker, R.M. and Mauer, W.A (1998) "Equine hoof wall density and morphology." *Journal of veterinary medical science*, 2013: 773-778.
Pollitt, C C. "The anatomy and physiology of the hoof wall." *Equine veterinary education.* 10, 318-325.

The sixth, and final, hypothesis tested, the difference in HGR between mares (n=5) and geldings (n=5). The results showed a highly significant result, in favour of mares growing at a faster rate ($P<0.001$). This corresponds with findings by Frackowiak and Komosa[38], however it contradicts findings from Butler and Hintz .[39] The findings are perhaps due to hormonal differences. But testing on a larger scale would be beneficial in order to develop a better understanding of this area.

The population group used for this study could not be tested to see if age affects HGR, as the sample group was too small.

The population range of horse numbers (n=10) was similar in size to other studies, Reilly et al tested (n=8)[40] and (n=12)[41] horses. Giving strong links with results. The data collected was stattistically strong, giving confidence in population size.

Nutrition has not been looked at within this study, as all the horses were managed differently and on varied diets. It would be noted that nutrition has an effect on HGR as found within the study of Reilly et al [42]. Further studies could be carried out looking at controlling the nutrition of the population, this could be used as a comparative study, to give a control on HGR and to test the locational points.

Concussive forces applied to the hoof both statically and dynamically, thus causing horn compression, have not been measured within this research. This is an area for further research horn compression maybe a factor affecting what is happening to the horn that farriers trim off the peripheral border of the

[38] Frackowiak, H. and Komosa, M. (2006) "*The dynamics of hoof growth of the primitive Konik horses (equus caballus gmelini Ant.) in an anual cycle."* Biological Rhythym Research.Vol. 37(3). 223-232,

[39] Butler, K.D. and Hintz, H.F. (1977) "Effect of level of feed intake and gelatin supplementation on growth and quality of hoofs of ponies." *Animal Science*. 44, 257-261.

[40] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine vetinary Journal.* 26, 51-57.

[41] [41] Reilly, J.D. Hopegood, L. Gould, L. and Devismes, L. (1998) "Effect of a supplementry dietry evening primrose oil mixture on hoof growth, hoof growth rate and hoof lipid fractions in horses: a controlled and blinded trial." *Equine veterinary Jounal.* 26, 58-65

[42] Reilly et al (1998)

capsule. The effect of compression on HGR is unclear. To remove external forces and compression from the equation would require a horse to be non-weight bearing for the research period, this would not be possible for ethical reasons. Limited research has been published to date on this subject.

At present, measuring in the manner of this paper and in the manner of Reilly et al[43] is all we have to build on regarding in the methodology for research of this kind. Further studies could use photographic and computer measuring systems to record data, results from this could be compared to studies carried out, to test levels of accuracy.

All areas in this paper that were tested showing a statistical significance, form a pattern with a link of HGR and external forces present, when the horse is dynamic.

The results within this research have shown associations with increased HGR and external forces. It would be unclear if this is due to reaction to force, or increased stimulants to the horn production through increased vascular supply. Tubule density variations also have shown relationships to decreased HGR which corresponds with load, areas of higher tubule density tend to have a slightly lower HGR in the fore feet but due to limited research in the hind feet no comparisons can be applied between tubule density and rates of HGR.

[43] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine vetinary Journal.* 26, 51-57.

Limitations of Study

As with all studies on living organisms, measuring a growing structure is not without challenges, total accuracy can not be guaranteed. However without measuring and collecting information no research could be carried out. Despite the acknowlegded levels of possible inaccuracies it is important that data from this area of study continues to be collected and analysed. Measuring innacruacy was attempted to be minimised by utilisation of a novel measuring criteria using 9 points of measurement.

The population within this study was varied in respect of: breed type, age, enviroment, gender and height. To find matching populations is extremely challenging when limited resources are avaliable. To the author's knowledge no studies have been carried out on a exactly matching population. In this study three of the horses (horses 1-3) were the same breed (Lusitanos) and were kept in the same environment with the same diet and work regime. Although only a small subsection, the results were encouragingly consistent with the overall data with the lusitano mare having faster HGR than the two geldings and the mare being the youngest lusitano measured. Similarly, in each case the mean front hoof HGR was equal or faster than the rear HGR and left front HGR was faster in 2 of the 3 lusitanos suggesting data robustness and perhaps ruling out environment, work-regime, diet and breed as a factors in HGR, more likely age, gender and horse/hoof size. Testing on a larger population will aid in gretaer understanding in this area.

This study was carried out over a three-month period, for the purpose of a preliminary study. This gave strong data matching other studies such as Reilly et al.[44] .It would be noted that some of the heel markers grew out by the end of the three-month period, data was collected before the feet were trimmed in these instances. The pilot study and the main study group were measured within different seasons. The pilot study was summer/autumn and the main body was

[44] Reilly, J. D. Cottrell, D.F. Martin, R.J. and Cuddeford, D.J. (1998) "Effect of supplementry dietry biotin on hoof growth and hoof growth rate in ponies: a controlled trial." *Equine vetinary Journal.* 26, 51-57.

winter/spring. The data did not show any disparity in rates of HGR within the seasons tested. The study could be repeated over 12 months (four test periods) to test in depth, seasonal variation in HGR in nine locational points.

The author acknowledges that he may have had an influence on the HGR in the locational regions with his trimming protocol and shoeing methods used. The study could be replicated by other farriers to see if individual farriery styles are significantly influential on the data collected. The use of different trimming methods and shoeing styles could be tested to give comparitive data in these areas. Further studies using the methods from this study could be carried out on bare foot horses, which would provide comparative results.

5. Conclusion

Whilst not all hypotheses had a positive result, it can be concluded that horses' feet grew at different rates in some inter and intra hoof regions. Results conclude that horses' front feet grew at a higher rate laterally compared to medially ($P<0.05$). The hind feet grew at a higher rate at the *dorsum*, compared to the heels ($P<0.001$). The front feet grew at a higher rate compared to the hind feet ($P<0.05$). It is noted that horses left front feet grew at higher rate compared to the right front feet ($P<0.05$).

It is also noteworthy that mares' feet grew at a faster rate than geldings' ($P<0.001$).

Farriery Relevence

The fundamental aspect of farriery is trimming the horse's foot. Greater understanding of its growth, form and function are paramount. Foot imbalance effects horses' soundness and performance, it is clear from the findings within this research that horses' feet do continually grow unlevel, when assessed in the manner within this study. Continued assesment and hoof reallignment is key to prolonging the horses working life. The results outlined within this study indicate that the horse's foot grows in different manners in larger locational areas, when comparing the intra foot mean HGR's collected. When trimming feet and asessing foot growth it is clear that what we see at the peripheral border is not always corresponding with the HGR at the coronary border of the capsule. But many links can be formed, with the data collected and farriery observation.These factors and the horse's gait should be considered and the conclusions applied when trimming and shoeing horses' feet. This study is a small piece of a big picture, aiming to aid in the growth of our industry's knowledge on the horse and its feet. Continued research in this area is needed, to aid in the understanding of the farriers influence on horse welfare, soundness and performance.

Manufacturers' Addresses

Dremel Europe, PO Box 3267, Breda, Netherlands.

Freelogix Limited, 1st Floor Anderson House, 27 Peterborough Road, Harrow, Middlesex, HA1 2AU, UK.

Microsoft excel®, Microsoft corporation, One Microsoft way, Redmond WA 98052-6399, USA.

Minitab® 17, Minitab Ltd, Brandon Court, Unit E1-E2, Progress Way, Coventry, CV3 2TE, UK.

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Williams, G. and Deacon, M. (1999) *No Foot No Horse*. Addington, Buckingham: (Kenilworth Press Ltd). Pages 11 and 37

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Appendices

Appendix I

Dear Horse owner,

I am commencing a study on rates of hoof growth around the hoof capsule. I am requesting your permission to use your horse within my research.

The research will be put forward in the form of a dissertation, in the aim to sit the communications part of the Fellowship of the Worshipful Company of Farriers.

The study will involve myself marking nine, 3mm holes around the hoof capsule, on all four feet of your horse. This will cause no damage or harm to your horse.

These markers will be measured on a six weekly basis, over a period of three months. Your horse will be trimmed and shod by myself over this period of research.

The names of horses and owners will be anonymized to ensure anonymity and confidentiality.

All data collected and any photographs taken will be secured safely.

If you are happy for your horse to be used within this research please sign below.

Owner:

Date:

Appendix II

Horse profiles

Horse 1

Breed- Lusitano

Sex - Gelding

Age - 19

Height – 15.2hh

Foot size

NF 313.2mm OF 319.3mm NH 325.3mm OH 338.1mm

Horse 2

Breed - Lusitano

Sex - Mare

Age - 6

Height – 16.2hh

Foot size

NF 315.1mm OF 315.9mm NH 303.4mm OH 305.6mm

Horse 3

Breed - Lusitano

Sex - Gelding

Age - 8

Height – 16.1hh

Foot size

NF 323.5mm OF 323.8mm NH 316.9mm OH 315.6mm

Horse 4

Breed - Irish sports horse

Sex - Gelding

Age - 13

Height - 16.2 hh

Foot size

NF 366.6mm OF 371.8mm NH 364.3mm OH 359.8mm

Horse 5

Breed - Connemara

Sex - Mare

Age - 20

Height – 15.2hh

Foot size

NF 309.9mm OF 309.4mm NH 296.5mm OH 298mm

Horse 6

Breed – Belgium warm blood

Sex - Gelding

Age 19

Height - 18hh

Foot size

NF 387.3mm OF 390.4mm NH 377.7mm OH 377.7mm

Horse 7

Breed - Cob

Sex - gelding

Age 19

Height - 15.2hh

Foot size

NF 425.3mm OF 428.5mm NH 412.7 OH 409.5mm

Horse 8

Breed - Thoroughbred

Sex - Mare

Age - 8

Height – 15.3hh

Foot size

NF	341.8mm	OF	333mm	NH	346.3mm	OH	337.4mm

Horse 9

Breed – Irish Draught

Sex - mare

Age - 11

Height – 16hh

Foot size

NF	370mm	OF	354mm	NH	361.5mm	OH	367.3mm

Horse 10

Breed – Cob x Arab

Sex - mare

Age - 14

Height – 15.3hh

Foot size

NF	376.1mm	OF	369.2mm	NH	368.1mm	OH	373.7mm

Appendix III

Data collection sheet

Horse number	Date	nf w	nf l	nf hw	toe	Lateral toe quarter	Medial toe quarter	Lateral quarter	Medial quarter	Lateral heel quarter	Medial hell quarter	Lateral heel	Medial heel
		of w	of l	of hw									
		nh w	nh l	nh hw									
		oh w	oh l	oh hw									

Appendix IV

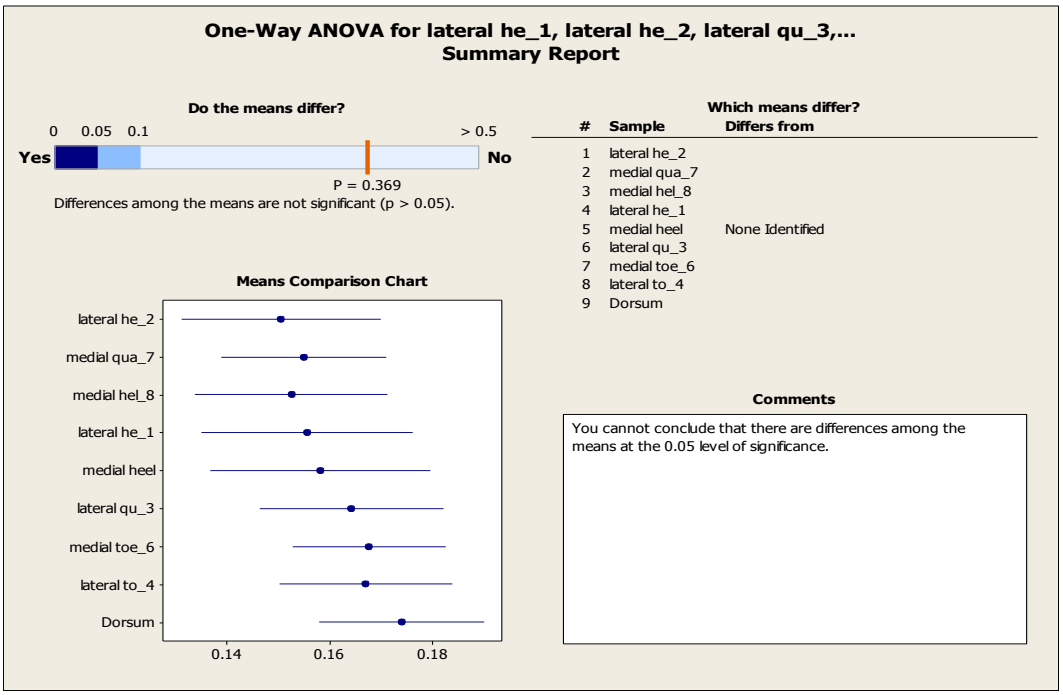

Figure 5: One-way ANOVA test for mean HGR in locational points.

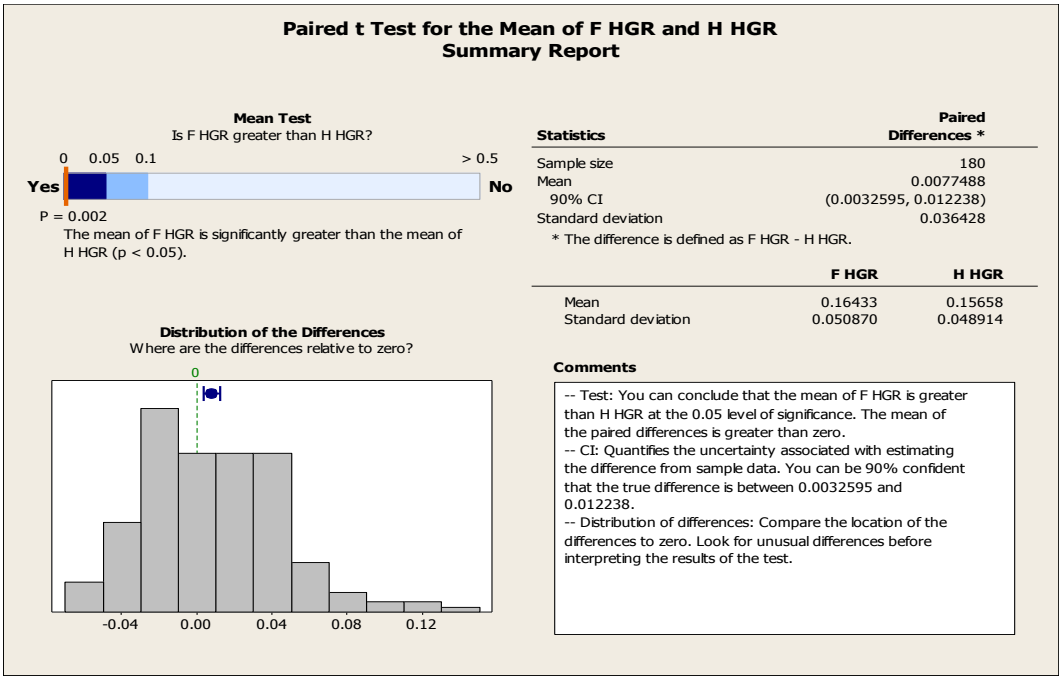

Figure 6: Paired t-test comparing front and hind mean HGR

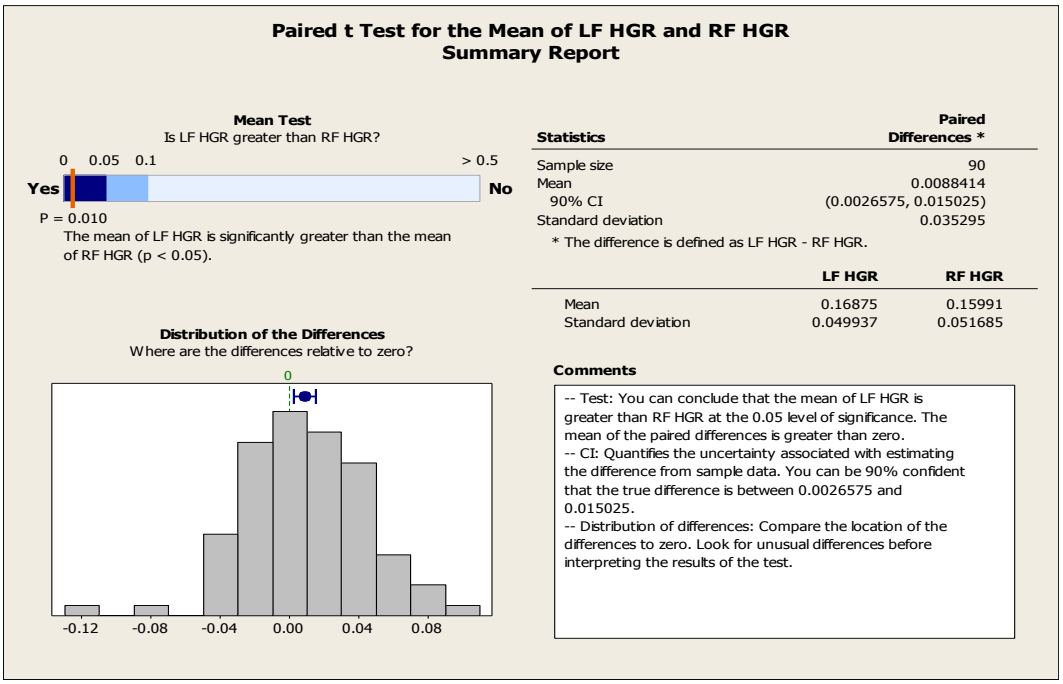

Figure 7: Paired t-test comparing left front and right front HGR

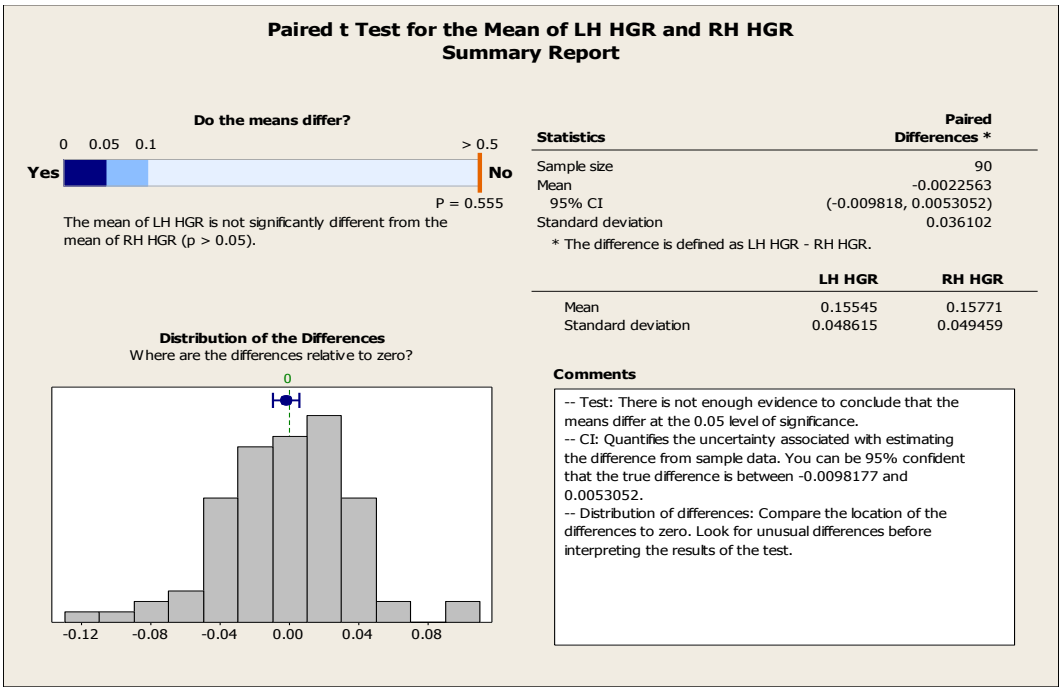

Figure 8: Paired t-test comparing left hind and right hind HGR

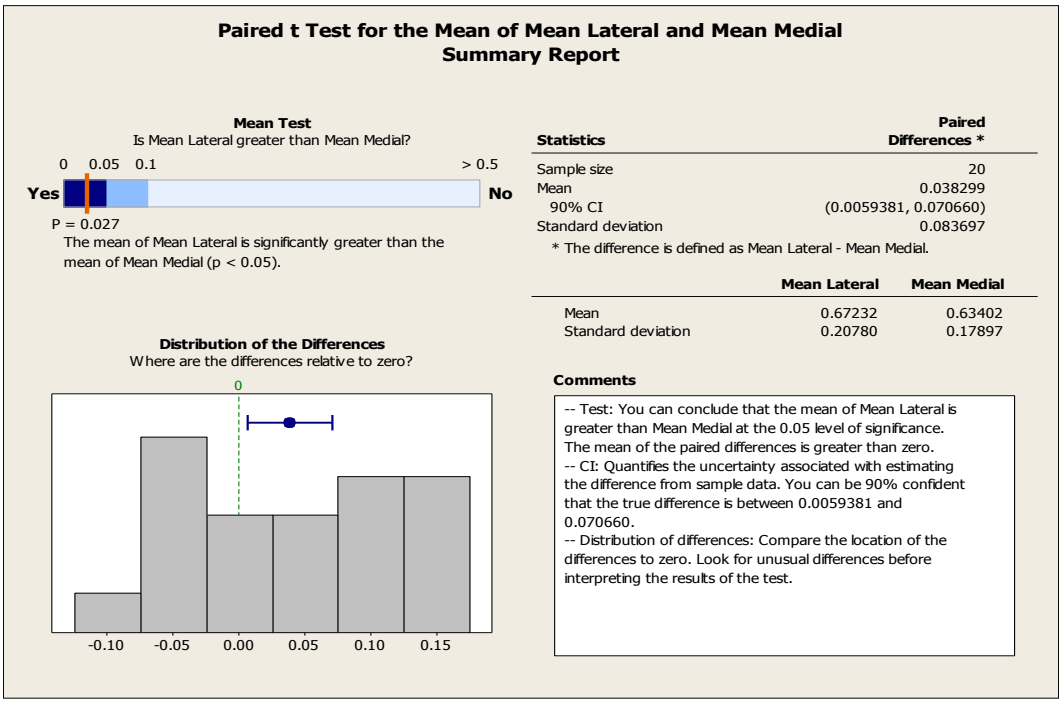

Figure 9: Paired t-test comparing front, lateral and medial HGR

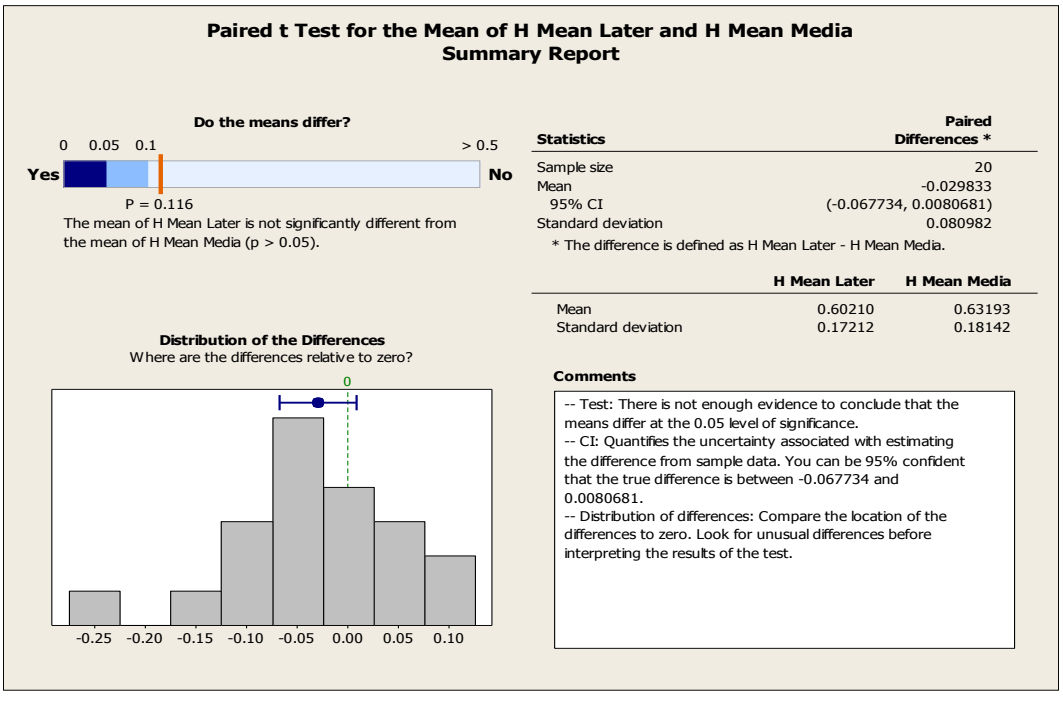

Figure 10: Paired t-test comparing hind, lateral and medial HGR

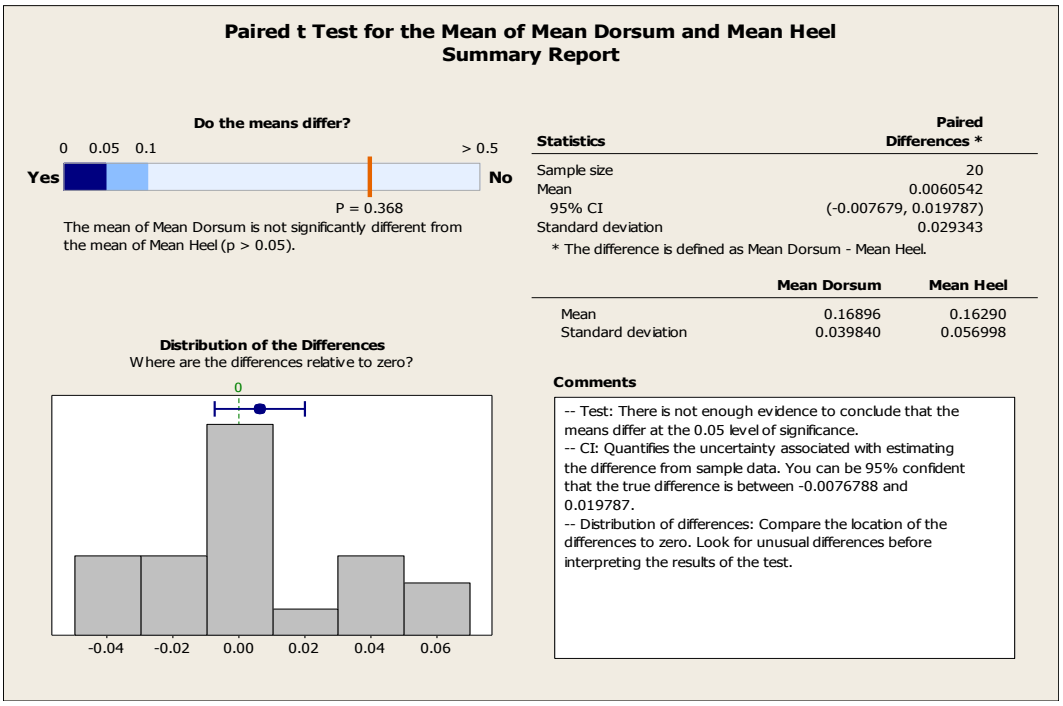

Figure 11: Paired t-test comparing front, Dorsum and Palmar HGR

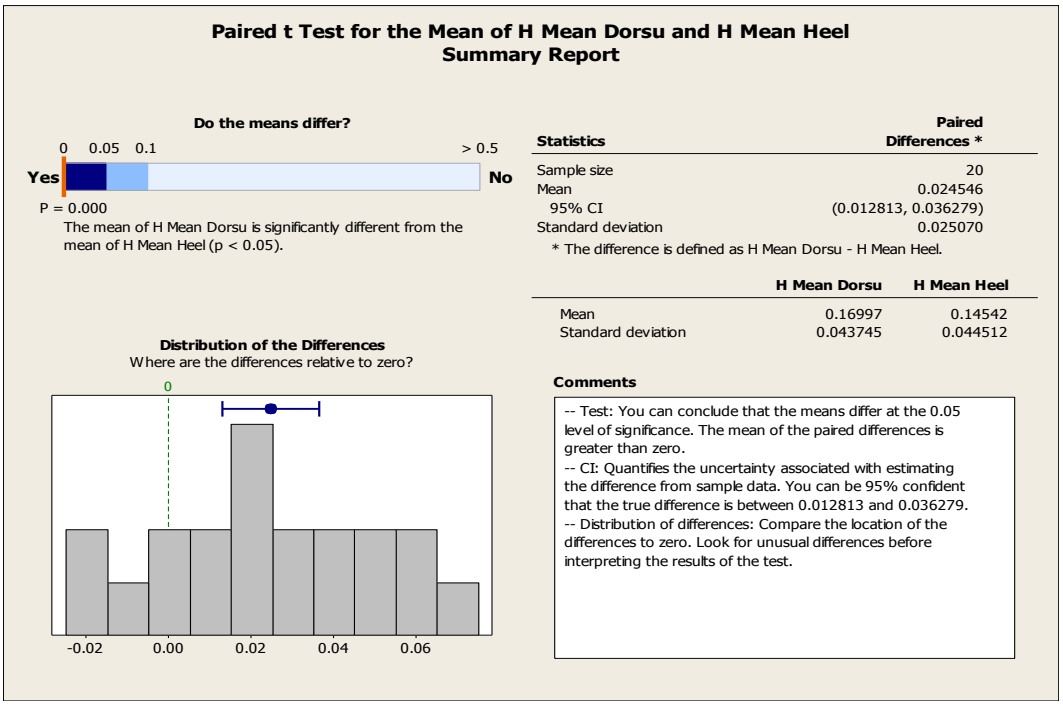

Figure 12: Paired t-test comparing hind, Dorsum and Plantar HGR

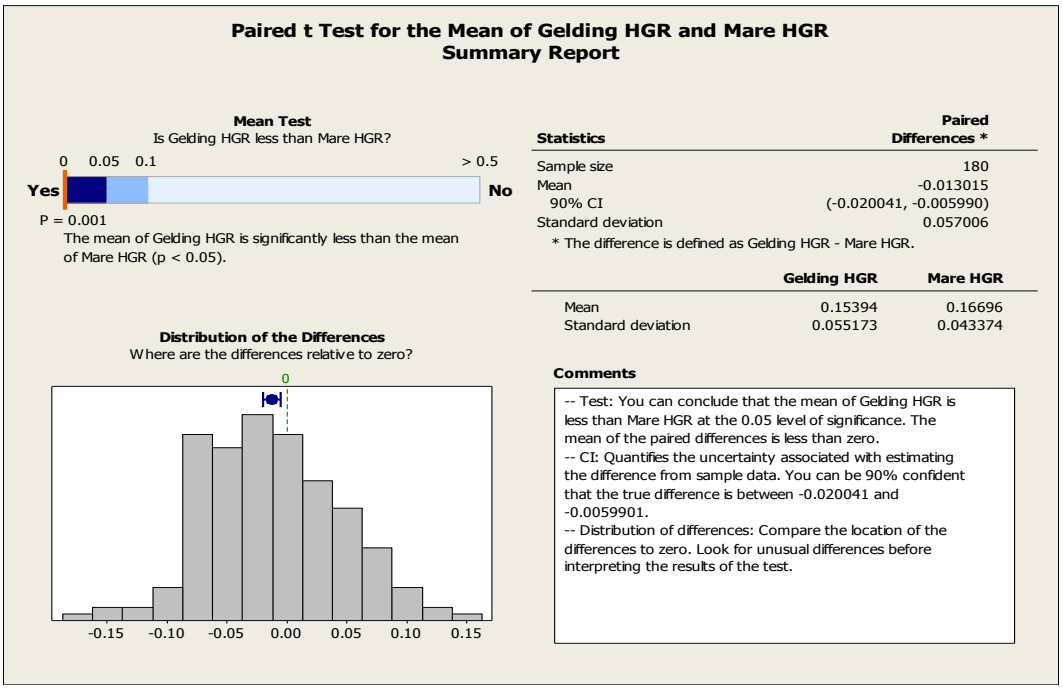

Figure 13: Paired t-test comparing Mare and Gelding HGR