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The Effect of Whole Body Vibration on Equine Hoof Growth

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THE EFFECT OF WHOLE BODY VIBRATION ON EQUINE HOOF GROWTH

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ABSTRACT

Equine foot pain can be a result of many conditions and disease processes, all of which lead to a loss of function in the horse. Rehabilitation and treatment is often focused on the regrowth of the hoof wall. When the horse loads the foot, pressure applied to the frog translates to the digital cushion and lateral cartilages, compressing the blood vessels, perfusing the area, and circulating blood back up the leg. The constant flow of blood through the foot stimulates growth of the hoof wall. Whole body vibration plates are thought to result in rapid muscle contractions and subsequently, increased circulation through the foot. An increase in hoof growth could prove whole body vibration beneficial as both a treatment option and a preventative care option for horses with damaged, injured, or slow-growing hooves. The objective of this study was to determine if horses treated using whole body vibration plates have significantly different hoof growth when compared to control horses. Data were collected over two separate 12-week time periods; Trial 1, from May-August 2016, and Trial 2, from August-October 2016. A total of 24 horses were randomly allocated to either the control (n=12) or experimental group (n=12) for the study duration, with the exception of the Trial 2 control group (n=10). During Trial 1, horses in the experimental group stood on the plate for 15 minutes per day, 5 days per week. During Trial 2, horses in the experimental group stood on the plate for 20 minutes per day, 5 days per week. The plate was set to vibrate at 50-55 Hz for both trials (manufacturer specifications). On the first day of each trial, a dremmel scoring tool was used to make a mark at the quarters of each hoof, just under the coronary band. As the hoof

grew, this mark allowed measurement of how much growth occurred by measuring the distance from the mark to the coronary band. Hooves were measured one day after the conclusion of each 12-week period. Mean hoof growth results for control and experimental groups were compared using independent t-tests with a cutoff significance level of $P<0.05$. For Trial 1, there were no differences between groups when comparing either overall growth for all hooves combined, or specific hooves (right front, left front, right hind, left hind). For Trial 2, a trend was noted ($P=0.058$) for increased overall hoof growth by the experimental group (mean 19.3 cm per hoof ± 2.5 cm) when compared to controls (mean 17.7 cm per hoof ± 1.2 cm). There were no differences when comparing specific hooves during Trial 2. This study showed no significant hoof growth rate increase with the use of whole-body vibration at 15 or 20-minute sessions, five days a week.

ACKNOWLEDGMENTS

I would like to thank the entire Otterbein Equine department for their support of this project; without their purchase of the whole-body vibration plate, none of this would have been possible. In particular I would like to thank Dr. Sheri Birmingham for her support and guidance on the entirety of this project, as well as Dr. Burk for all of her assistance. I would also like to extend a special thank you to the women who made Trial 2 possible: Haley Sutton, Audrey Bauman, Sarah Gray, and Leah Koskinen. I quite literally could not have completed this research without them.

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INTRODUCTION

The equine industry revolves around equine performance and competition, which relies heavily on the health and soundness of the animals involved. It is estimated that in about 80% of lameness cases, lameness is a direct result of pain located in the equine foot (Jury et al., 2015). The equine foot can be defined as the structures from the coronary band down, including the pedal bone, navicular bone, navicular bursa, distal end of the deep digital flexor tendon, laminae, hoof wall, digital cushion, frog, and sole (Figure 1).

Anatomy of the Equine Foot

The exterior structures of the hoof include the wall, sole, coronary band or coronet, and frog (Figures 2 and 3). The hoof wall is the primary weight bearing structure of the foot. It continuously grows from its origin at the coronary band and envelopes the coffin bone. The hoof wall may be categorized into three sections: the toe, quarters, and heel. When the hoof is lifted from the ground and viewed from the solar surface, the wall makes up the outer ridge of the hoof (Morris, 2015). The wall is made of three layers (Figure 4). The periople, the outermost layer, is a shiny layer that functions much like a human cuticle. It is often rasped or sanded off during routine farrier work. The remaining outer layer is termed the stratum tectorium, which functions much like a human fingernail. The middle layer, the stratum medium, is the densest of all three hoof layers. The final layer, the stratum interium, is the sensitive layer containing the laminae, which are tiny vascular projections that connect the hoof wall to the coffin bone (Ross and Dyson, 2011).

When the horse is standing, the wall and frog come into contact with the ground, whereas the sole does not. The sole lies between the palmar surface of the coffin bone and inner hoof structures and the ground. The sole supports the weight of the internal structures of the foot, but does not support weight in relation to the ground (Sellnow, 2006). A thick sole depth protects the internal structures of the foot from injury should the horse land on a sharp object. A thin sole compromises the safety of these internal structures, and a horse with thin soles may often suffer from bruises to the coffin bone and laminae.

Equine hoof growth is impacted by multiple factors, including peripheral blood flow to the feet, weight distribution on the hoof, climate, nutrition, level of exercise, metabolism, physical condition, parasitism, wear, and age (Butler and Butler, 2004). On average, the equine hoof grows 3/8 inch per month (Butler and Butler, 2004). The exact mechanism by which hooves grow is unknown. The hoof wall itself is avascular and completely cellular (Bertram and Gosline, 1987). Any required fluids or nutrients are provided by diffusion through a basal membrane that lies next to the vascularized dermis. Germinal epithelium cells are produced at the coronary band. As the hoof wall grows, those cells migrate distally towards the toe. Desmosomes between the primary and secondary laminae layers separate and reform, allowing this movement to occur (Parks, 2003). The hoof wall is composed primarily of keratin, produced by cell division at the proximal border of the wall. Keratin cannot regenerate or remodel once produced, because the keratinocytes from which it is derived die in the final stages of their differentiation (Bertram and Gosline 1987). These keratinocytes are found within the tubules of the hoof wall. Tubules are continuous, stretching from the origin at the coronary band to where the hoof wall makes contact with the ground (Figure 5). Inspection of hoof wall tubules show that keratinocytes mature at a right angle to the hoof wall, and form a keratin matrix to create the horny layer of the hoof wall (Kaneps and Turner, 2004).

Most of the specialty farrier work that is completed revolves around the effort to stimulate or encourage blood flow to the foot to encourage hoof growth by putting small amounts of pressure on the frog of the foot (Ritmeester and Blevins, 2015). The frog, composed of highly elastic tissue, is located just distal to the digital cushion, an elastic yielding structure. When a horse is properly trimmed and/or shod, the frog bears some weight but not the primary load (Butler & Butler, 2004). The frog is highly elastic cartilaginous tissue, and when compressed, expands inward onto the digital cushion (Ross & Dyson, 2011). This creates a flow of blood by acting as a pump every time the foot is loaded (Figure 6). Horses with good hemodynamic flow show better hoof structure than their counterparts, showing that blood flow is a primary factor in providing the necessary nutrients for hoof growth (Bowker et al., 1998). When the horse loads the foot, the pressure applied on the frog translates to the digital cushion. The digital cushion then expands against the lateral cartilages. This compresses the blood vessels, perfusing the area and sending blood pumping back up the leg. The constant flow of blood that this creates through the foot stimulates repair and growth of internal structures (Ross & Dyson, 2011). The coronary band and lamina, from which the hoof wall and sole respectively grow, experience this increased blood flow and react with growth. Too much pressure on this sensitive area can in itself cause lameness, but small amounts of gentle stimulation can be beneficial (Ross & Dyson, 2011).

Multiple conditions and disease processes result in equine foot pain. In such cases, rehabilitation and treatment is at least in part focused on the regrowth of the hoof wall and/or sole (Ross & Dyson, 2011). Horse owners spend large amounts of money paying for specialty farrier care and supplements that are advertised to promote hoof growth in order to maintain or restore their animal's soundness (Buffa et al., 1992).

Common Conditions and Disease Processes of the Equine Hoof

An abscess is a common infection of the hoof, often resulting in a pocket of pus. The pressure as the horse loads the foot often renders the horse non-weight bearing. Puncture of the pocket results in a reduction of pain and lameness in the horse, but the infection itself must be walled off and grow out with the hoof. Typically, this takes 10-28 days given typical hoof growth rates (Butler & Butler, 2004).

Hoof wall cracks are fissures in the hoof wall, often caused by environmental factors or imbalances in the hoof. Treatment often involves binding the hoof together with clips, stitching, patching or filling with composite; however, the only way to return the hoof to its typical form and structural integrity is to let the hoof grow until the crack has completely grown out. Depending on the severity of the case, this may take several months (Butler & Butler, 2004).

Thrush is a common bacterial infection of the frog, collateral grooves, and central sulcus. Thrush thrives in the anaerobic environment produced by deep recesses in the hoof. Once diseased tissue has been removed and the bacteria killed, any sensitive tissues exposed and damaged by the bacteria must grow out and heal. Depending on the depth of damage, this typically takes 10 days to a month for the hoof to grow out (Butler & Butler, 2004).

Laminitis is a very serious systemic disease, which causes the separation of the laminae, resulting in the loss of connection between the hoof capsule (wall and sole) and the pedal bone. The bony column of the leg may sink through the hoof (a process called founder) and often the necrosis of inner tissue may cause secondary abscesses. If the disease process is stopped, the horse must regrow a healthy hoof capsule with good laminar connection. Often an entire hoof must be regrown, a process that may take a year or more (Butler & Butler, 2004). Laminitis may also cause avulsion of the hoof, which is the loss of the hoof capsule by tearing or sloughing. This causes extensive damage to the underlying sensitive laminae. If the entire hoof capsule sloughs off, this takes on average a year to grow out (Butler and Butler, 2004).

A bruise or puncture wound to the hoof is typically caused by a sharp trauma by a rock, nail, or other such object. Prognosis depends upon the severity and depth of the damage, and often secondary conditions such as an abscess may set in. Hoof growth will heal the damage as long as the pedal bone, navicular bone, or navicular bursa have not been severely damaged (Butler & Butler, 2004).

Whole Body Vibration

Whole body vibration was a therapy first used in human medicine for the treatment of a variety of conditions, including osteoporosis and neurodegenerative disease (Sharififar et al., 2014). Whole body vibration plates vibrate at least 20 to 60 times per second. These mechanical stimuli are transmitted to the body where they stimulate in turn sensory receptors, most likely muscle spindles, which leads to the activation of the alpha-motoneurons and initiates muscle contractions (Delecluse et al., 2003).

The vibrations simulate falling, which results in extremely rapid muscle contractions. These rapid contractions aid in increasing circulation and moving blood and lymph (Grampp et al., 2015). Research in humans proves that vertical whole body vibration is capable of increasing muscle activity (Delecluse et al., 2003).

There are currently two different types of whole body vibration plates in production and use. One uses oscillating motion whereas the other uses vertical vibration. Proponents of oscillating vibration claim that vertical vibration is too stressful on the body's bony column, and creates a jackhammer-like effect. Proponents of vertical vibration claim that oscillating vibration creates an unnatural circular movement in the joints of the body which, over time, results in the destruction of joint tissues. Neither vertical nor oscillating whole body vibration has any researched or reported negative long-term use side effects.

While whole body vibration with horses is a quickly growing trend, research is only now being completed testing its effects on horses. In one pilot study, whole body vibration produced a decrease in serum cortisol and creatine-kinase values; however, no other measured levels were affected (Carstanjen et al., 2013). Cross sectional ultrasonography proved that whole body vibration did increase the cross-sectional area and symmetry of the *multifidus* muscle of the thoracolumbar spine (Halsberge, 2016). Bone mineral content of stalled horses receiving whole body vibration therapy was observed to be consistent with those of stalled horses receiving light exercise (Hulak et al., 2015). In a study testing the effect of whole body vibration on chronically lame horses, no statistically relevant change in lameness score was noted over periods of 30 or 60 days using 30 minute sessions twice a day, five days a week (Halsberghe et al., 2017). In all studies, horses showed no adverse effects to the whole body vibration therapy.

MATERIALS AND METHODS

Otterbein University IACUC committee approval was granted prior to the start of this research. A total of 24 horses were randomly allocated to either the control (n=12) or experimental group (n=12) for the entire study duration, with the exception of Trial 2 control group (n=10), as two horses were removed from the study due to management reasons. All horses belong to Otterbein University's Austen E. Knowlten Equine Center in Westerville, Ohio, where they participate in the lesson program as well as wet lab procedures.

Horses used were varied in age (6 to 25), weight (440-730 kg) and breeds (Thoroughbred, Warmbloods, Irish Sport Horse). All horses were on a similar diet of complete feed (Purina Ultium and Purina Senior) and grass hay. Mineral supplements and water were freely available to all horses. No horses were on any type of supplement known to contain any hoof-growth-inducing qualities. Turnout of each horse did vary, as did ridden exercise time.

The whole body vibration plate chosen was a vertical vibration plate from the company Equivibe. This brand was chosen due to affordability and structural durability. The plate was installed in stocks as to comfortably restrain the horses during their whole body vibration treatments.

Data were collected over two separate 12-week time periods; Trial 1, from May-August 2016, and Trial 2, from August-October 2016. During Trial 1, horses in the experimental group stood on the plate for 15 minutes per day, 5 days per week. During Trial 2, horses in the experimental group stood on the plate for 20 minutes per day, 5 days per week. The plate was set to vibrate at 50-55 Hz for both trials (manufacturer specifications). On the first day of each trial, a dremmel scoring tool was used to make a mark at the quarters of each hoof, just under the coronary band. As the hoof grew, this mark allowed measurement of how much growth occurred by measuring the distance from the mark to the coronary band. Hooves were measured one day after the conclusion of each 12-week period.

RESULTS

Statistical Analysis System (SAS) version 9.3 was used to analyze the data. PROC UNIVARIATE was run to check normality assumptions before performing inferential statistics. Mean hoof growth results for control and experimental groups were compared using independent t-tests (PROC TTEST), with a significance level of $P<0.05$. Equality of variance of Trial 1 ($Pr>F$ 0.050) indicated use of the Pooled variance test statistic. There was a trend for increased hoof growth by the experimental group ($P=0.066$). For Trial 1, there were no differences between groups when comparing either overall growth for all hooves combined, or individual hooves (right front, left front, right hind, left hind) (Figure 7). Equality of variance of Trial 2 ($Pr>F$ 0.042) indicated use of the Satterthwaite approximation. A trend ($P= 0.058$) was noted for increased overall hoof growth by the experimental group (Figure 8). P-values did not indicate statistical significance when each hoof was individually analyzed across control and experimental groups for Trial 1 or Trial 2 (Figures 9 and 10).

DISCUSSION

This study showed no significant hoof growth rate increase with the use of whole-body vibration at 15 or 20-minute sessions, five days a week, at 50-55 Hz. Treatment at 20 minute sessions led to increased new growth compared to the control or 15 minute session groups. A trend was noted for both experimental groups in Trial 1 and Trial 2. No negative effects were noted and the horses reacted well to treatment.

Several limitations were noted in this study. Horse exercise was varied during the study. Some horses worked for longer and more frequently than others, and some jumped more regularly. Additionally, some horses were on stall rest for short periods at a time during the study due to unrelated illness or injury. As exercise increases blood flow, this had the potential to skew results in this study.

Environmental conditions changed throughout the study as summer turned to fall. Interestingly, though traditionally it is thought that summer denotes an increase in hoof growth, we saw the trend in increased hoof growth during the fall. This may indicate that whole body vibration has the ability to provide continuation of peak hoof growth despite changes in season/climate.

Further study with a larger sample size may show significant differences between control and experimental groups. While statistical analysis did not indicate and association between whole body vibration and hoof growth within the parameters of this study, the trend noted in Trial 2 may indicate that increased time on the whole body vibration plate may lead to statistically relevant hoof growth. While within this trial we adhered to the manufacturer's recommended time limit of 10-15 minutes per session at 50-55 Hz, further research of safe treatment parameters could increase the time per session as well as altering frequency values. Increasing sessions from 5 times per week to 7 could also prove effective. While this potential was noted within this study, we were limited by available manpower. Putting each horse on the plate for thirty minutes once a day would have added up to 6 hours; that time was not available as students without the capability of hiring someone else into the position.

Recent studies published since the start of this research showed that increased treatment time of 30 minutes twice per day did not produce any adverse effects in the horses (Halsberghe et al., 2017). There is little research on frequency safety or efficacy parameters of whole body vibration of equids.

Further research on the effects of whole body vibration on equines is greatly needed. Since the introduction of the plate into the Otterbein facility, several riders have noted that the use of the plate seems to reduce muscle stiffness in their horses. It is possible that increased blood flow moves lactic acid out of muscles as well as bringing necessary nutrients and oxygen to muscles prior and post-exercise. Whole body vibration may provide a means of inducing blood flow to regions of the equine body that typically lack blood flow and therefore struggle to heal (ligaments, tendons, joints). Whole body vibration also seemed to have a calming and relaxing effect on horses, which may warrant further investigation.

Continuing research on equine hoof growth should take into account what we know about equine podiatry and vascular flow. Several complementary and alternative veterinary medicine (CAVM) treatments offer intriguing possibilities. Shockwave, high-powered laser therapy and acupuncture are all documented to provide increased blood flow to the targeted region. Though this study focused on how peripheral blood flow to the feet affects hoof growth, many other hoof growth factors have room for study. Though we know climate and season change appears to have an effect on hoof growth, the exact reasons why are yet uninvestigated. Similarly, metabolism, physical condition, parasitism, wear, and age effects on hoof growth all have much room for research and study.

FIGURES

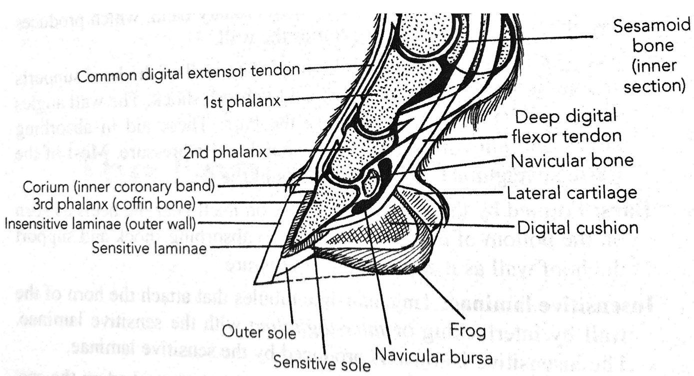

Figure 1. Lateromedial view of the internal structures of the equine foot, including the pedal bone, navicular bone, navicular bursa, distal end of the deep digital flexor tendon, lamina, hoof wall, digital cushion, frog, and sole (Harris, 2014).

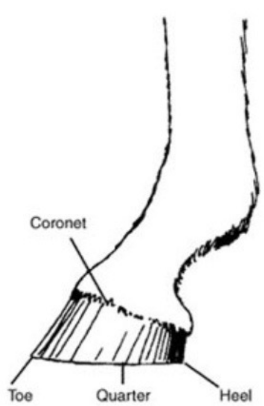

Figure 2. Lateromedial view of the external structures of the foot (McClure, 1999).

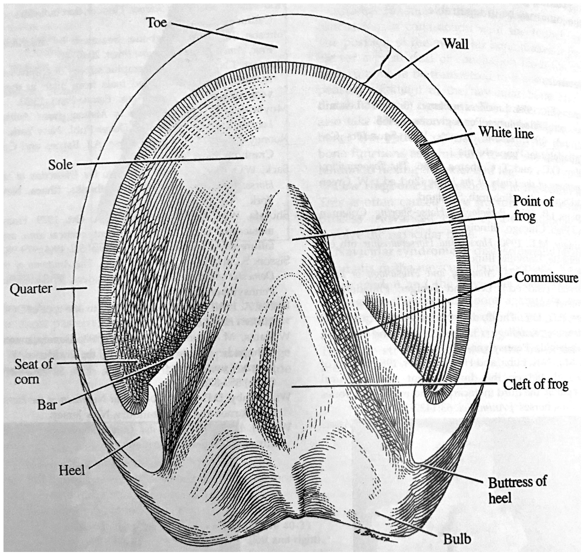

Figure 3. Palmar view of the external structures of the foot (Butler and Butler 2004, drawing by L. Sadler).

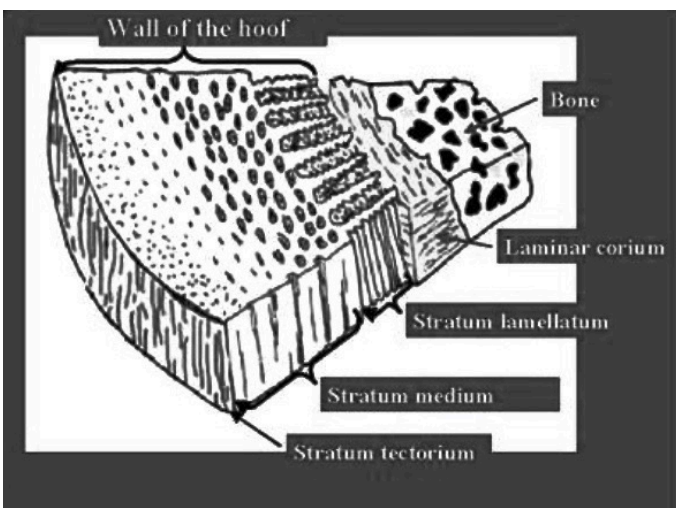

Figure 4. Layers of the hoof wall (Ownby, 2002).

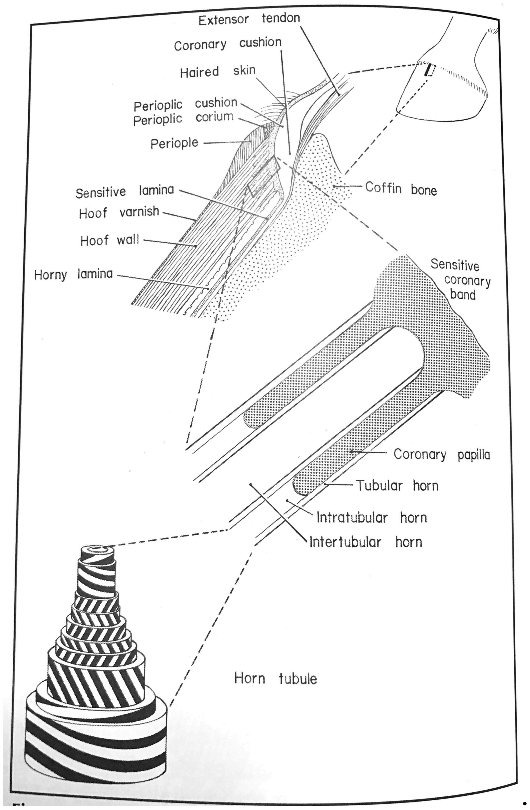

Figure 5. Detail on the structure of the hoof wall (Butler & Butler, 2004).

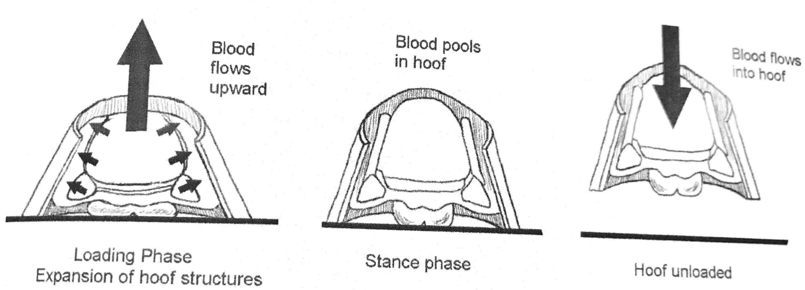

Figure 6. Diagram demonstrating the loading and unloading forces in the equine hoof (Harris, 2014).

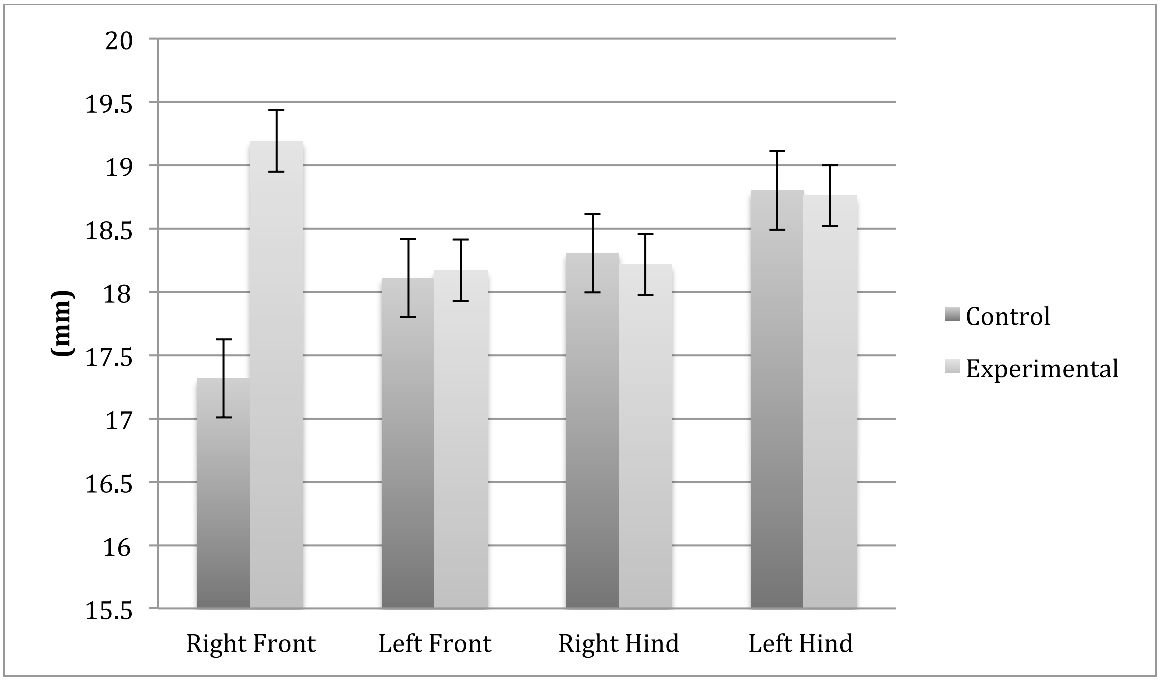

Figure 7. Trial 1 mean hoof growth of control and experimental groups . Error bars indicate standard error.

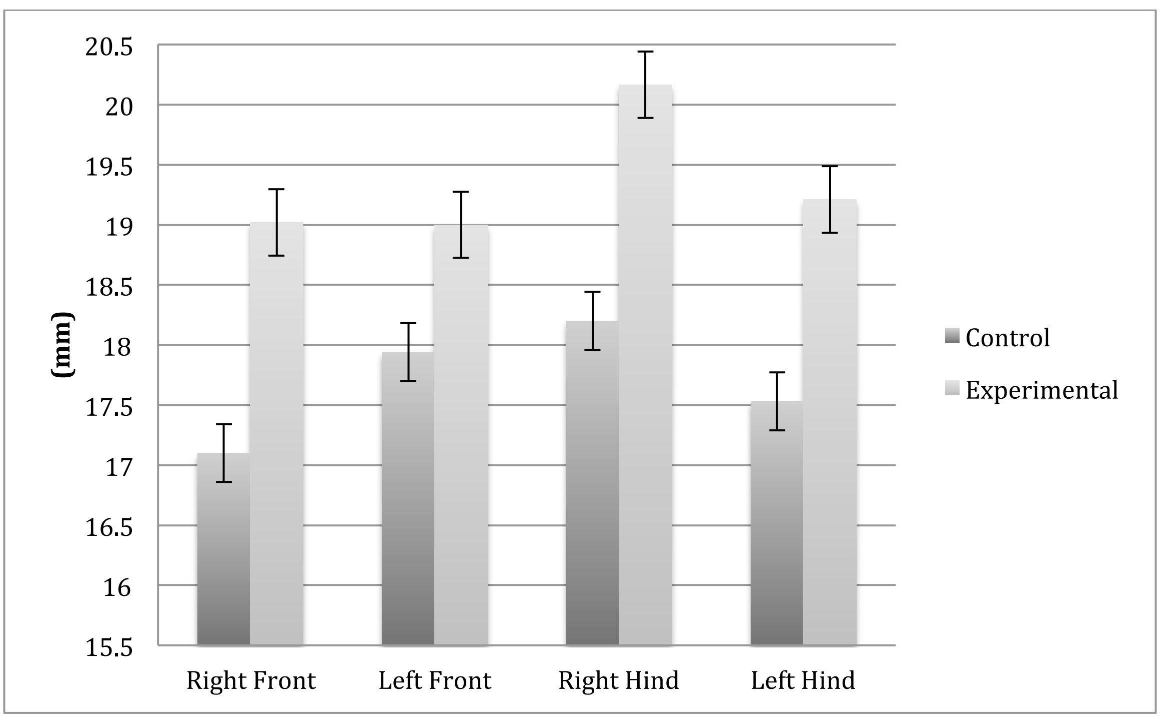

Figure 8. Trial 1 mean hoof growth of control and experimental groups. Error bars indicate standard error.

	Mean ± Standard Deviation (mm)	Range
RF Control Growth	17.32 ± 2.56	9.59
LF Control Growth	18.11 ± 2.93	9.12
RH Control Growth	18.31 ± 3.29	9.04
LH Control Growth	18.8 ± 3.59	11.39
RF Experimental Growth	18.25 ± 2.75	11
LF Experimental Growth	18.14 ± 3.02	10.99
RH Experimental Growth	18.26 ± 3.2	12.59
LH Experimental Growth	18.78 ± 3.53	11.89

Figure 9. Trial 1 hoof growth data. Growth was analyzed for each hoof to find mean, standard deviation, and range

	Mean ± Standard Deviation (mm)	Range
RF Control Growth	17.1 ± 2.08	7.48
LF Control Growth	17.9 ± 2.86	9.89
RH Control Growth	18.2 ± 1.48	5.66
LH Control Growth	17.53 ± 1.95	5.79
RF Experimental Growth	18.15 ± 2.94	11.59
LF Experimental Growth	18.52 ± 2.35	9.89
RH Experimental Growth	19.27 ± 3.5	14.1
LH Experimental Growth	18.44 ± 2.79	12.14

Figure 10. Trial 2 hoof growth data. Growth was analyzed for each hoof to find mean, standard deviation, and range

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APPENDICES

Appendix 1. Measured hoof growth (mm) for Trial 1. Hoof growth was calculated as final measured value minus initial measured value for each hoof.

	Right Front	Left Front	Right Hind	Left Hind
Control 1	19.19	16.84	18.12	21.23
Control 2	15.09	15.35	16.71	14.56
Control 3	19.97	13.13	22.32	22.88
Control 4	12.84	22.25	14.4	18.05
Control 5	17.98	17.63	15.63	18.25
Control 6	17.42	19.46	21.55	18.91
Control 7	16.04	21.23	23.44	24.68
Control 8	22.43	21.79	17.97	23.1
Control 9	17.84	20.31	22.63	18.01
Control 10	15.41	15.6	15.31	13.29
Control 11	18.15	15.55	16.36	17.65
Control 12	15.42	18.18	15.22	14.94
Experimental 1	23.11	23.96	25.34	21.25
Experimental 2	19.59	16.94	17.57	15.48
Experimental 3	20.19	19.15	18.2	24.07
Experimental 4	21.27	21.24	19.79	18.57
Experimental 5	18.85	17.33	18.57	25.18
Experimental 6	19.2	17.91	17.24	17.62
Experimental 7	21.12	22.33	20.44	21.6
Experimental 8	12.11	13.77	15.12	15.48
Experimental 9	18.5	18.53	20.61	15.58
Experimental 10	19.63	18.11	18.07	20.02
Experimental 11	16.85	12.97	14.92	15.77
Experimental 12	19.88	15.81	12.75	14.51

Appendix 2. Measured hoof growth (mm) for Trial 2. Hoof growth was calculated as final measured value minus initial measured value for each hoof.

	Right Front	Left Front	Right Hind	Left Hind
Control 1	17.4	18.03	17.56	15.06
Control 2	14.71	12.33	18.81	15.59
Control 3	20.89	17.26	19.26	17.75
Control 4	.Lost to follow up.			
Control 5	17.39	15.67	18.21	15.61
Control 6	16.65	19.75	17.79	16.72
Control 7	.Lost to follow up.			
Control 8	18.14	18.65	19	19.75
Control 9	16.45	22.22	17.45	16.38
Control 10	13.41	16.78	17.6	18.66
Control 11	18.89	17.23	20.99	18.83
Control 12	17.05	21.51	15.33	20.85
Experimental 1	22.67	19.98	19.04	21.42
Experimental 2	20.14	19.86	16.34	15.9
Experimental 3	14.67	16	19.61	16.56
Experimental 4	16.35	18.83	23.76	20.6
Experimental 5	19.23	17.76	25.25	26.74
Experimental 6	21.58	20.58	24.75	10.15
Experimental 7	20.07	20.71	13.92	14.6
Experimental 8	13.91	17.69	15.62	17.38
Experimental 9	25	22.19	28.02	20.63
Experimental 10	19.76	19.35	20.94	20.37
Experimental 11	19.22	16.44	18.68	17.49
Experimental 12	15.64	18.7	16.06	19.63