12-2017

Effects of Rider Experience Level on Horse Kinematics and Behavior

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EFFECTS OF RIDER EXPERIENCE LEVEL ON HORSE KINEMATICS
AND BEHAVIOR

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Animal and Veterinary Sciences

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by
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December 2017

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ABSTRACT

Large riding lesson programs are an essential part of the horse industry. To meet demand and remain profitable, lesson barns sometimes require horses to work multiple times a day with different rider levels. There is little guidance as to the behavioral and physical effects of such protocols, so lesson program managers have limited scientific evidence upon which to base horse management and welfare decisions. The current data regarding horse and rider interactions includes motion pattern variability, trunk and spine kinematics and force plate analyses. While these data are helpful to explain scenarios that can affect the horse with an accomplished rider or singular rider, to our knowledge no data exist that examine how riders with varying skill levels affect limb joint kinematics. This research was designed to determine if rider experience level affects horses' movement, possibly resulting in increased physical effort by the horse. Secondarily, we aimed to determine if rider level affects changes in behavior patterns when ridden. Riders (n=8) were paired by skill level (beginner or advanced), and horses (n=8) were paired by sensitivity level (reactive or nonreactive). Horse and rider pairs were then randomly blocked into a repeated Latin square design using rider ability and horse sensitivity as factors. The Latin Square design created sixteen trials, each comprised of five passes in a prescribed path at the trot. Kinematic analysis was completed using high-speed video capture, and joint angles were calculated using digitizing software through MATLAB (MathWorks Inc., Natick, MA). An ANOVA was performed using JMP (SAS Institute Inc., Cary, NC) based on the repeated Latin square design. The Latin Square design allowed adjustment for horse sensitivity and rider level. The ANOVA suggested no differences in the measured joint angles between rider skill level or horse sensitivity level. To ensure that a subtle rider effect wasn't missed, all the kinematic measurements were subjected to a combined overall analysis with a combination of graphical techniques and MANOVA. While the combined analysis revealed no overall trends in the combined kinematic variables ($p = 0.327$), two variables, the front fetlock and stifle, trended towards significance of $p=0.077$ and $p=0.096$, respectively. Behaviors were quantified based on a designed ethogram and willingness scale, and each trial was videoed for analysis. Behaviors were analyzed by ANOVA, with the same Latin Square design that adjusted for rider level and horse sensitivity. There were no differences in behavior measurements as a result of rider skill level or horse sensitivity. While our data suggest no differences between beginner and advanced rider groups, future studies may reveal effects on joints during an entire stride cycle, in different gaits, and for longer periods.

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CHAPTER ONE

INTRODUCTION

Riding lesson programs are a large part of the equine industry. These programs act as a gateway for people into the industry because of the affordability and lowered responsibility of not having to own your own horse to be able to ride. There are many facilities around the country that offer lessons across all disciplines. Due to a high demand for lessons, these facilities have to make management decisions with their lesson horses that may have them working multiple times a day and with a varying level of rider. Until this point, there has been little research regarding welfare of horses in these lesson programs. The always-developing management practices for horses generally revolve around maintaining and enhancing the general health of the horses, i.e. weight, foot care, gut health, injury management, etc. The overall aim is to keep the horses healthy in all respects as well as utilizing them for riding as long as the horses show no signs of pain or distress.

Horses are known to exhibit certain behaviors that show they are uncomfortable (either mentally or physically) when ridden, such as bucking, rearing, chomping the bit, head slinging, and many others. Developed horsemen learn to recognize these signs and try to address the problems- creating the art of horse training. In lesson horses, which have usually been through a training program that determines them “safe” or conditioned to riding, the horses’ riding behaviors develop in response to the inexperienced riders that ride them. The horses may develop a head flip from pulling on the reins, or become slow to move up in gait in response to leg possibly from an unbalanced rider creating lack of balance in the horse. These behaviors can then change or cease when there is a change of rider to a more advanced or balanced one.

While the instructor can see the behaviors, the forces and strain on the horses' body might not be seen. Research has shown that riders create different forces on the horses' body just by weight and balance changes (Merkens *et al.*, 1993; Dow *et al.*, 1991; Weishaupt, 2002, 2004; Clayton *et al*., 1999). It has also been seen that different riders can change the gait, and synchrony gets disrupted with a beginner rider compared to an advanced rider. A rider can influence the impulsion and carriage of the horse, with a "well-ridden" horse thought to exhibit greater self-carriage with ease to its gait. Beginner riders are just learning balance and the basics of holding their legs and hands correctly to communicate with a horse and they tend to not have the ability to help the horse position its body to move efficiently and fluidly. While there are differences in the movement when ridden differently, there is no proof that one way is more detrimental or beneficial for the horse than another.

The main goal of this study was to determine if there was any difference in the joint angles of a group of lesson horses when ridden by advanced and beginner riders at the trot. The application of the work is to determine if riders contribute to impact on horse joints, exacerbating potential "wear and tear" over time. Secondarily, we aimed to determine if differences in behaviors of horses in response to the different levels of riders existed.

CHAPTER TWO

LITERATURE REVIEW

Gait Biomechanics

Biomechanical study of locomotion in the horse uses kinematics and kinetics to analyze gait and body movement. Kinematics is the description of how body parts move in space without regard to forces that cause the movement, whereas kinetics examines the forces that act upon movement (Hodgson *et al.*, 2014). Basic locomotive analysis can happen within a single stride cycle. A single stride is measured from one footfall to the next of that same limb and contains two phases- stance and swing. Stance phase can be measured from first hoof placement on the ground until toe lift-off of that same hoof, and swing phase is the portion of the cycle where the limb is off the ground (Clayton, 2016). These stride cycles can vary by gait, breed, height, and weight of the horse. Some of the most common measurements of a stride in kinematics are stride length, duration, and frequency. Stride length is quantified by measuring the distance from one footfall to the next placement of the same foot- or stance phase to the next stance phase. Stride duration is the time elapsed between footfalls; stride frequency can be calculated using duration and is typically expressed in “strides per minute” (Clayton, 2004).

Kinetic analysis is used to examine the forces acting between the horse and the environment that produce movement. Some of the most common forces of interest are ground reaction forces, which are forces produced from the ground to the object in contact. Since these forces aren’t detectable by human sight, many sensors and gauges have been developed and studied to help identify the magnitude of forces produced during the movement of the horse. Force is a vector, which means that it has a magnitude and a direction. Ground reaction forces (GRF) can be classified into a three-dimensional model with vertical, longitudinal and transverse directions (Clayton, 2004). The vertical GRF is the most direct in measuring force during weight bearing and has the greatest magnitude, making it the most commonly studied vector of force. The vertical GRF is typically measured using a force plate (Hodgson *et al*., 2014; Weishaupt, 2008). One interest for developing this technology for application with horses is to be able to more objectively assess lameness in performance horses.

Force plate studies have shown vertical GRF graphed versus time to peak at mid-stance phase at the trot. Differences in timing of peak force between forelimbs and hind limbs have also been seen. (Merkens *et al.*, 1993; Dow *et al.*, 1991; Weishaupt, 2002, 2004). By isolating the footfalls at mid-stance phase, the compression of the joints is at maximized. Calculating the angles of these joints during peak force could reveal the presence of a physiological change to locomotion other than stride length, duration, and frequency as well as a connection between kinetics and kinematics.

Rider Kinematics

Horseback riding is a unique sport, as it requires two independent beings to come together in harmony as one and complete difficult tasks such as jumping, sharp turning, gait variations and quick stops. In order for a horse to do these tasks accurately, a rider must be actively involved in the process as well. Proper rider position across multiple disciplines is defined as the rider's ear, shoulder, hip, and heel align to an imaginary vertical line. The ability to hold this position takes time and practice to develop but is necessary in advancing the level of riding.

Several studies have shown that there are quantifiable differences between beginner and advanced riders. By measuring rider joint angles during walk, posting trot, sitting trot and canter, it has been shown that beginner riders consistently have a more "closed" or acute hip angle. The larger hip angle of the advanced rider may be correlated to the lower leg sitting more directly underneath the trunk of the rider, thus creating a more "vertical" position (Schils *et al.*, 1993; Eckardt *et al.*, 2016; Kang *et al.*, 2010).

In other studies, advanced riders tended to have less forward pitch of the trunk of their body through all gaits, meaning that they tended to have consistently wider hip angles and an upright upper body. (Eckardt *et al.*, 2016; Münz *et al.*, 2014). Beginner riders have the tendency to have greater variations in trunk pitch, which contributes to decreased stability in their seat. Advanced riders seem to more closely match the motion pattern of the horse they are riding compared to beginner riders. They appear to do this by adjusting the tilt of their pelvis to maintain stability in the saddle (Eckardt *et al.*, 2016; Münz *et al.*, 2014; Lagarde *et al.*, 2005). Knowing that there are differences seen between advanced and beginner riders suggests that these changes in position and balance could cause a change in the horse as well.

Rider Effects on Horses

Kinematics of the horse can change with a rider's influence. It has been shown that a rider, when ridden with a balanced and connected seat, leg, and upper body, can add stability to the motion pattern of the trunk of the horse as well as reduce variation in velocity and acceleration when compared to an unridden horse (Peham *et al.*, 2004). This increased stability shown with an advanced rider could suggest that there is a lack of or decreased stability with a beginning rider, which may be more taxing on the horse in the long run.

A horse and rider pairing is typically referred to as a "horse-rider system" (Peham *et al.*, 2001). This system has been shown to vary in harmony depending on riding skill level. Peham and colleagues (2001) reported deviations of the movement over time between professional and recreational dressage riders. The professional horse-rider systems showed lower deviation of angular velocity at the trot than that of the recreational riders. Dressage scores for riders, judged by a professional dressage rider using the International Federation of Equestrian Sports (FEI) guidelines during riding measurement trials, were then compared, revealing that the more "harmony" the horse-rider system is in, the higher the score (Peham *et al.*, 2001). Similarly, Lagarde and associates (2005) demonstrated that a novice rider had a more rigid seat and had a harder time following the two-beat up and down motion of the horse compared to an advanced rider. The authors attributed this to the greater flexibility and deeper seat measured in the advanced rider compared to the observed "straighter and tense" seat of the novice (Lagarde *et al.*, 2005). It can be derived from this information that skill level could lead to a greater physiological effect on the horse that is ridden by a beginner rider on a regular basis, such as those utilized within a riding lesson program.

Riding Behaviors in Horses

There is little known about how a rider's level affects behaviors of the ridden horse. There have been multiple studies that examine behavioral patterns related to signs of stress, such as cortisol levels and heart rate. In a study by Ellis and colleagues (2014), two groups of horses (nervous and calm) were examined during feeding, riding, and turnout. During these times, data on exhibited behaviors, heart rate, and salivary cortisol levels were collected. Their observations showed differences in behaviors between the excitable and calm groups of horses during feed time, turn out, and riding times (Ellis *et al.*, 2014). A similar study by Rietmann and associates (2004) looked at a select group of behavioral parameters and heart rate within a group of warmbloods during a riding exercise test. During this study, the researchers found a correlation between heart rate and behaviors they deemed as stress related (high head position ($r = 0.79$), movement patterns- explosive ($r = 0.65$) and deviation from equal pace ($r = 0.71$), and stopping ($r = 0.59$)). By comparing a similar group of horses, these researchers demonstrated that these behavior patterns rely less on the personality of the horse and are a general response to stress that can be seen across all horses (Rietmann *et al.*, 2004). Signs of physiological stress and riding behaviors were also correlated in a study conducted by Hall and colleagues (2014), in which they observed that a lower head position while being ridden positively correlated with increasing salivary cortisol levels. Increased eye temperature, recorded using infrared thermography, was shown to correlate with the amount of time the horse's nose was behind the vertical. The change in eye temperature is an indicator of sympathetic nervous system activation due to circulatory system changes (Hall *et al.*, 2014).

There are hundreds of observable behaviors seen in horses. These behaviors are catalogued in tables called ethograms. An ethogram is a quantifiable dataset of specific observable behaviors and can be done across all species. Riding behaviors in horses can be taken from these ethograms and used in studies to correlate the specific behaviors and physiological changes to determine potential harm to the animal. Knowing that there are behaviors that are related to stress parameters, such as elevated heart rate, makes observing these signs more important when considering welfare concerns within riding programs. Ignoring behaviors linked to stress across a long period of time could cause faster psychological deterioration of the horse and cause chronic stress.

Conclusion

As horses travel across the ground, there are forces acting upon their body from multiple directions. Ground reaction forces are of greatest interest as we look at horses' biomechanics and movement. Stride and force analyses have shown that vertical GRFs reach their peak during mid stance phase (Weishaupt, 2002, 2004). This means that the greatest amount of force acting to flex the joints is at this point and could impose the greatest influence on joint deterioration.

Sufficient evidence has shown that a rider has the ability to influence the stability and motion patterns of the horse (Peham *et al.,* 2004; Lagarde *et al.*, 2005). There have also been sufficient findings showing significant positional differences between beginner riders and more developed riders (Schils *et al.*, 1993; Eckardt *et al.*, 2016; Münz *et al.*, 2014). This information on stride kinetics and rider involvement in locomotion led us to question the effect that riders may have on joint flexion of horses during peak force of mid-stance- particularly in lesson program horses. Secondarily, we questioned if there was a connection between stress-related riding behaviors and differing riding levels, which might be clarified using ethograms and a willingness scale. Therefore, this study was designed to test these questions using horses utilized within a lesson program. Results from this study may provide more information in managing workload efforts that could impact horse welfare based on the variation in work of horses. The hypothesis of the study was that there would be a difference seen in joint angles between advanced and beginner riders as well as a difference in riding behaviors seen in these horses.

CHAPTER THREE

MATERIALS AND METHODS

This study was designed to determine if there are differences in horses' limb joint angulations when ridden by either advanced- or beginner-level riders. Procedures for this study were approved by the Clemson University Institutional Animal Care and Use Committee (2016-033), and the Institutional Review Board (IRB 2016-129). Eight female riders (n=8), ranging in age from 15-24, were paired by skill level (beginner or advanced) using a survey that determined years of experience and riding competency, and through consultation with a professional riding instructor. Riders were also paired by height, weight and limb segment length measurements. Eight horses (2 mares, 6 geldings), ranging in age from 10 to 20 years old, were paired by breed, conformation, and sensitivity level to rider aids (reactive or nonreactive). Sensitivity level of horses was determined by the professional instructor, who was familiar with all of the horses through use in their lesson program on a regular basis. All horses were of similar fitness level and were in light to moderate use during the time of the study. Horse and rider pairs were then randomly blocked into a repeated Latin square design using rider ability and horse sensitivity as factors.

Horses and riders had 2.54 cm circular markers placed on limb joints for kinematic measurements. Markers were placed on the lateral side of the horses' left fore and hind limb joints at easily palpable anatomical locations outlined by Galisteo and colleagues (1996). Two research assistants were trained by the principal investigator to insure proper placement on each joint.

A straight path (15.24 m) was designated and marked in the riding arena to collect video from trials in which horses used a trot under saddle. The camera was set perpendicular to the path, 9 m from the rail and half way down its length (7.62 m). Riders were asked to begin trotting at the first marker and then walk at the second marker. The video camera (GoPro Hero3+) filmed at 120 frames per second, started recording at the first marker, and stopped once the horse passed the second marker. This was repeated 5 times for each horse/rider pair.

To calculate limb kinematics from the videos, the positions of joint markers were digitized using the MATLAB (Math Works Inc., Natick, MA) routine DLTdv3 (Hedrick, 2008) and MATLAB software. Markers on each joint were selected using the program to create coordinates. These coordinate points were used to specify vectors representing limb segments. The angle (ang) between two limb segments (A and B) could then calculated using the standard equation (Hamilton, 1989):

$$\mathbf{cos(ang) = [(A \bullet B)/(vlengthA)*(vlengthB)]}$$

where (A•B) is the dot product of the vectors, and vlengthA and vlengthB are the lengths of vectors A and B, respectively. All joint angles were a single value collected at one moment in mid-stance phase; where the joints were determined to peak in amount of flexion.

Behavior videos were captured using a (Sony DCR-SX63) camera at “real time” speed or 30 frames per second. This camera was set at a wide view of the whole arena and recorded the entirety of each riding trial. An exclusive ethogram of riding behaviors (Table 3.1) and a riding willingness scale (Table 3.2) was created based off of previously published data (Ellis *et al.*, 2014; Rietmann *et al.*, 2004). Each video was evaluated in triplicate using the willingness scale and any designated behaviors tallied as seen. Willingness scores were given to each trial (defined by completion of 5 passes for each rider) and analyzed with ANOVA.

Table 3.1. Exclusive Ethogram: Descriptions for Riding Behaviors in Horses

Behavior	**Description**
Head Toss	Abrupt rotating or tossing of the head
Ear pinning	Ears pressed firmly back against head and neck
Head Turning	Movement of the head and neck without cue from rider
Head Shaking	Repeated movement of head
Tail Swishing	Exaggerated movement of the tail; may seem like more of a wringing.
Bit Chomping	Mouth and tongue manipulation of the bit without aids from rider.
Defecation	Expulsion of feces.

Table 3.2. Willingness scale for evaluating each trial

1	Slow response time, may exhibit stress behavior, exaggerated encouragement needed from the rider.
2	Calm and relaxed movement, needs extra encouragement for forward movement but responsive
3	Adequate response to rider’s aid, continues forward without much encouragement for entirety of gait.
4	Moves forward with light aid, may pull to go faster, may take extra encouragement to break down to walk. Slightly agitated state.
5	Moving forward without any aid, moves in an agitated state, ignoring rider in downward transition

An ANOVA was performed for both kinematic and behavior data using JMP (SAS Institute Inc., Cary, NC) based on the repeated Latin square design. The repeated Latin Square design allowed adjustment for rider level and horse sensitivity effects. The model utilized was:

$$\mathbf{y = \mu + R + H + R*H + B + E}$$

where R is rider level, H is horse sensitivity and B are the randomized Latin squares. To ensure a rider effect was not missed, a combined analysis was utilized, and then a MANOVA was completed using the same statistical model above. Significance was declared at $p < 0.05$, with trends towards significance designated a $P < 0.10$.

CHAPTER FOUR

RESULTS

Analysis of variance tests were run based on the previously stated model for all joints of interest. Figure 3.2 shows the response of the targeted joint angles to rider level (beginner and advanced). There is a trend towards significance seen in the front fetlock ($p=0.077$) and the stifle ($p=0.096$). Using these data, a combined analysis of the data was performed by looking at direction of the response means of the joints to see if there was an overall trend across all joints using this statistical model. Table 3.3 includes the numerical response means. The term "Greater Joint Flexion" refers to the riding level that caused a more flexed or acute joint angle (Figure 3.1 shows angles calculated for each joint). It can be seen that no obvious overall trend for joint flexion is present between beginner or advanced riders. The front fetlock and hock showed more flexion, based on the mean of the angles, when ridden by an advanced rider, whereas the knee, elbow, stifle, and back fetlock showed greater mean flexion of angle with the beginning group. To ensure that an overall rider effect on joint angles was not overlooked, a MANOVA was completed (Table 3.4). This analysis showed no difference ($P = 0.3270$) between the beginner and advanced riders.

Figure 3.1. Illustration of angles measured for each joint of interest during mid-stance of trot..

Figure 3.2. Mean joint angles by rider level Advanced (A) or Beginner (B)

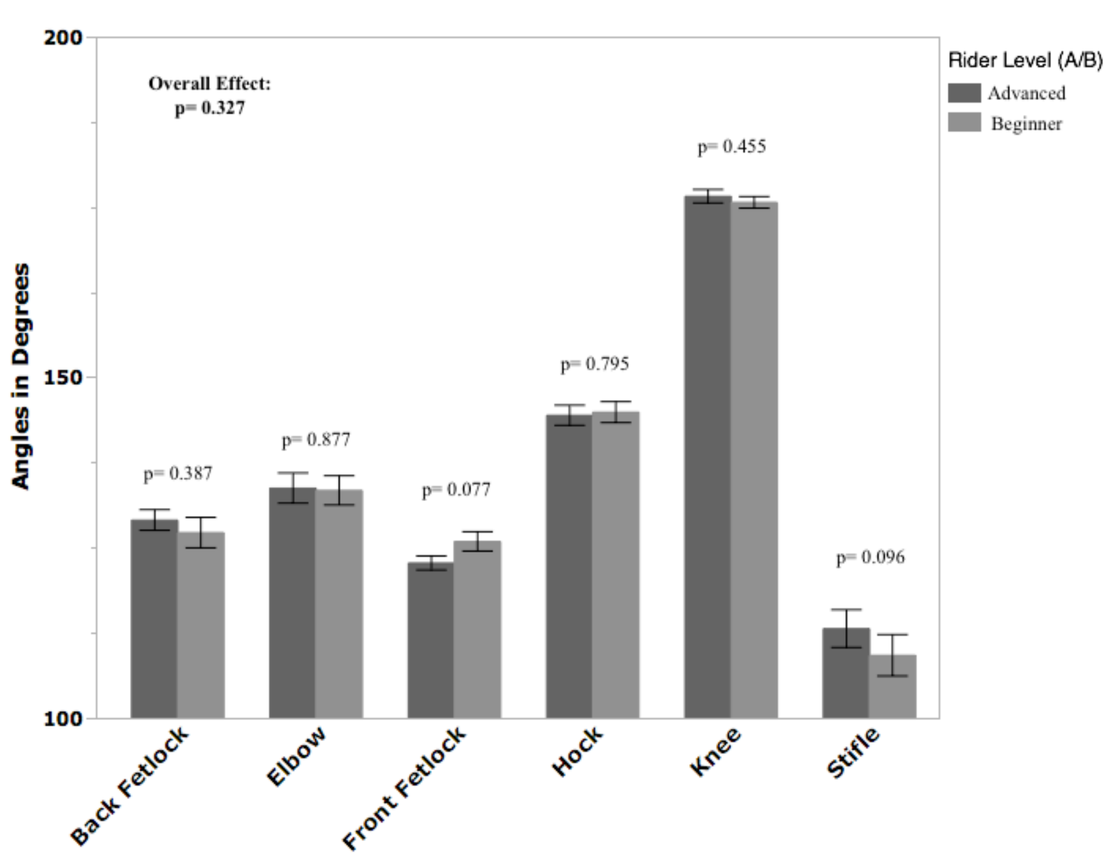


Table 3.3. Response means of joints to advanced (A) vs beginner (B) riders

Response	A Mean (st err)	B Mean (st err)	Significance	Greater Joint Flexion
Front Fetlock	122.73 (1.50)	125.92 (1.49)	0.0774	Advanced
Knee	176.57 (1.03)	175.66 (1.03)	0.4553	Beginner
Elbow	133.73 (2.80)	133.34 (2.80)	0.8766	Beginner
Back Fetlock	129.05 (1.57)	127.22 (1.56)	0.387	Beginner
Hock	144.42 (1.89)	144.88 (1.89)	0.7949	Advanced
Stifle	113.11 (4.12)	109.19 (4.12)	0.096	Beginner
Stride Length	373.42 (22.018)	366.216 (22.013)	0.8589	N/A

Table 3.4. MANOVA F-test results for overall effect of rider level on the horse

Test	Value	Exact F	DF	Prob>F
F Test	4.36	1.87	7	0.3270

Figure 3.3 details the response means of the specific observed behaviors from this study's ethogram. There were no differences among any of the behaviors of interest for horses ridden by either beginner or advanced riders. Note that some behaviors were not observed during the riding trials, thus an overall score of 0 was recorded for that behavior frequency. Figure 3.4 shows no difference for the means of the willingness scores for each trial by rider level (p= 0.309).

Figure 3.3. Mean behavior response scores by rider level Advanced (A) vs. Beginner (B)

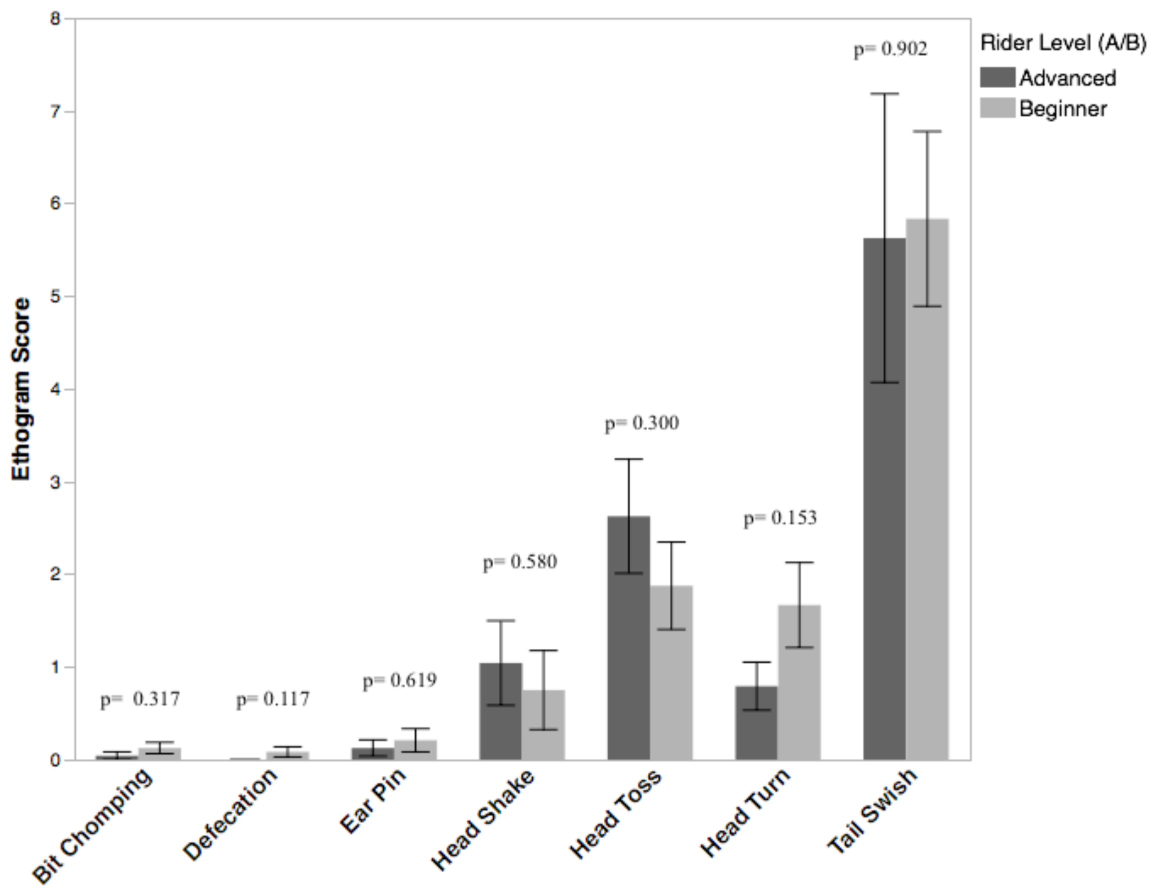
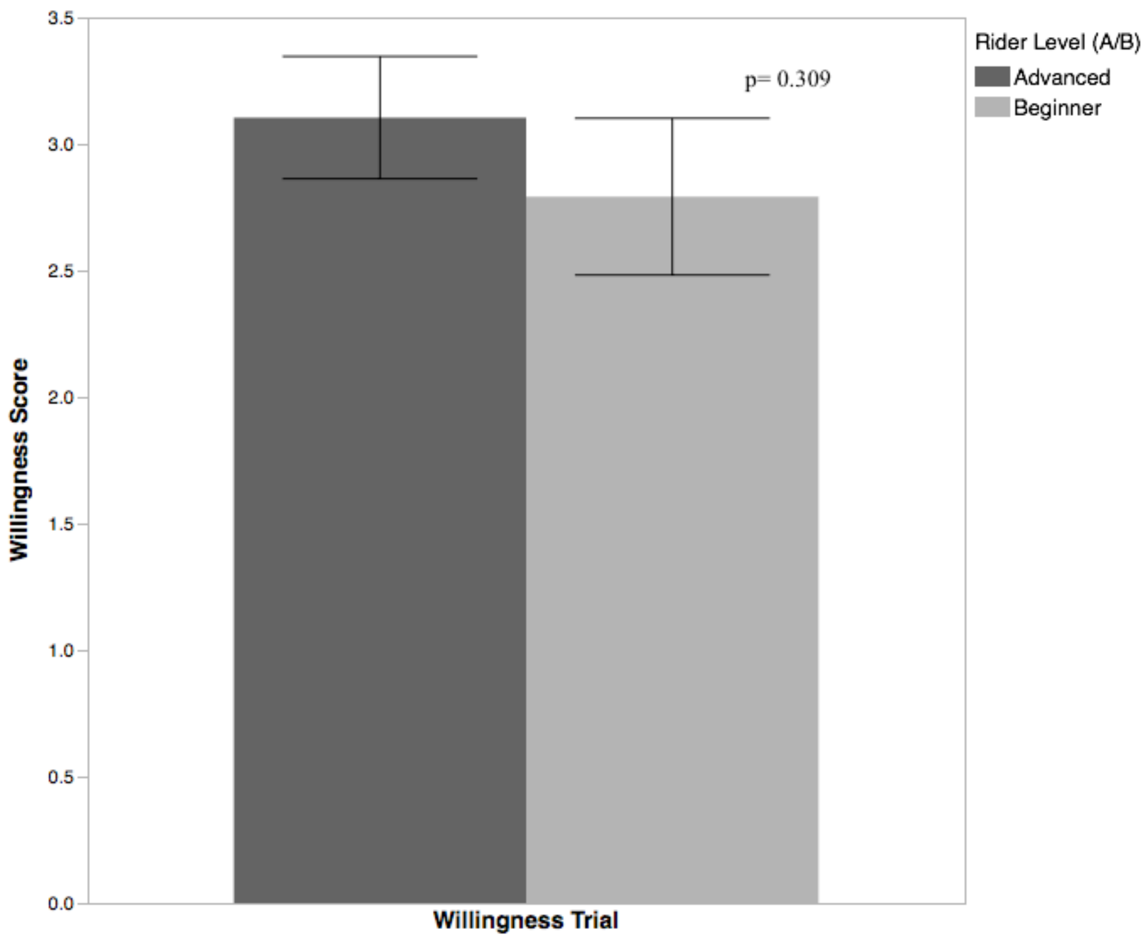


Figure 3.4. Mean willingness trial scores by rider level Advanced (A) vs. Beginner (B)



CHAPTER FIVE

DISCUSSION

Kinematics

Previous research has shown that there is a high level of variability in riding position between beginning and advanced riders. One of the highest consistencies seen in the literature is the difference in hip angles and riders' trunk position. A beginner rider tends to have a more acute hip angle and a more forward trunk that varies positionally throughout the gait, while advanced riders tend to have a more open hip angle keeping the trunk closer and more consistently around vertical (Eckardt *et al*., 2016; Kang *et al*., 2010; Schils *et al*.,1993).

These balance variations between rider ability levels seemingly also coincide with studies looking at motion pattern variability of the horse's trunk between advanced and beginner riders. Lagarde and colleagues (2005) demonstrated that a novice rider had a larger lag time behind the horse's gait compared to an advanced rider. They reported that a novice rider tensed against the motion and created larger lag time from the motion of the horse (Lagarde *et al*., 2005). In 2001, Peham and colleagues demonstrated differences in synchronization of the horse with either professional or recreational riders. The beginner riders showed more deviations in the motion pattern, leading to the conclusion that beginners cause more "instability" to the horse-rider system (Peham *et al.,* 2001).

While the current study did not examine full motion patterns of the horse and rider, it did aim to give a snapshot of the differences in joint angulation during peak force on the limbs in mid-stance. The goal was to further examine differences on the effects of rider level on horse motion. Although we didn't see an overall difference ($p = 0.3270$) of all joint angles between rider levels, there were two statistical trends noted on individual joints when looking at the combined analysis of rider level effects. The front fetlock trended towards significance ($p = 0.0774$) where the advanced rider groups caused a tendency for greater flexion in the fetlock (mean angle 122.73° ± 1.50) than the beginner rider group (mean angle 125.92° ± 1.49). A second statistical trend was noted in the stifle joint, where the beginner group caused a tendency for greater joint angle flexion ($p = 0.096$; 109.19° ± 4.12) than the advanced riders (113.11° ± 4.12). Although we did see trends in these two specific joints, it is interesting to note that there was not a consistent trend in joint flexion between the two riding levels (Table 1). The difference in trends between the fore and hind limbs could be attributed to how the different riding levels position themselves on the horse. Research has shown that a beginner rider is less stable and tends to follow behind the motion (Lagarde *et al*., 2005; Peham *et al.,* 2001), which may lead to more variation within the hind limb and more possible compensation within the hind limb instead of the forelimb.

The riders in these trials were analyzed to determine if there were differences between the beginner and advanced groups. Results are included in Appendix A, as this was not a major objective of the study, but rather used as an internal standard to ensure differences between rider level. The angles of the elbow, hip, and knee of each rider during each trail were calculated using the same method as the angles of the horses' limbs. An ANOVA revealed a statistical difference of knee angle between advanced and beginner riders ($p = 0.0055$), with the advanced riders having a more acute knee angle compared to the beginner group (Appendix A2). This difference in knee angle follows those seen in a study by Eckardt and colleagues (2016) that analyzed different levels of rider at the trot. They found that the advanced riders demonstrated a more acute knee angle and a smaller range of motion (Eckardt *et al.,* 2016). The differences in this study's riders' positions increases confidence that the rider groups had different skill levels and thus had the potential to influence the horse differently.

Though no statistical differences (at $P \leq 0.05$) were seen in the present study, further studies could be warranted. The use of permanently affixed markers, while more invasive, would yield more definitive results. More sophisticated high-speed video quality and automated digitation of markers could reduce variation used to identify joint angles. This study also gives merit to looking at actual GRF differences with horses ridden by different rider levels. Using force plates or shoes could reveal more subtle changes in force that may further illuminate differences in forces placed on the horse when ridden by riders of varying ability. However, the results of this study may indicate that horses ridden at the trot by riders of varying levels do not create substantial differences in joint flexion of the limbs, and thus rider level may not create undue strain on the horse when ridden at the trot. Another possible interpretation of the results of this study is that it is just one moment of flexion and didn't track the full stride of the horse. The horses could have greater compensation for the riders at this one point in time, but perhaps have differences in other parts of the stride cycle. Further work in this area may assist riding instructors and riders to determine the true physical effort placed on the horse when ridden by an inexperienced versus experienced rider. This type of information could ultimately assist the horse industry in making better decisions regarding the usage of horses in a riding or training program.

Behavior

The current study showed no differences in behavior of the horses during riding sessions. It should be noted that the behaviors selected for the ethogram used in this study do not account for all possible individual behaviors that could have been exhibited among horses. Also, it is important to note that only three of the seven behaviors that were defined were observed by researchers during analysis.

Behavior studies tend to be variable when multiple researchers are tasked with scoring or determining the degree of a behavior exhibited (Hall *et al*., 2014). The current study showed high variability when determining overall trial score and when assessing tail swishing as an individual behavior. A tail swish became difficult to assess during this trial in particular as they were completed during the summer and in an outdoor riding arena where flies could not be controlled. This caused difficulty in determining whether or not a tail swish was from a rider or from the environment.

Horse disposition could have also affected results. While we did establish sensitive and less sensitive horse groups to try to capture a greater personality range, all horses were in a steady lesson program for multiple years and are conditioned to changing riders. Horse sensitivity, irrespective of rider level, may be an interesting focus of further research, with application to assist the horse industry in matching horse-rider combinations and minimizing physical and mental strain on the horse when ridden.

CHAPTER SIX

CONCLUSION

In conclusion, though there is reasonable belief based on past research that there are physiological differences in horses when ridden by varying levels of riders, this study showed no significant differences when looking at joint angles and specific behaviors during riding under the study conditions. Since we were unable to directly relate ground reaction forces to joint angles, we believe that looking specifically at vertical GRFs during mid-stance could lead to more meaningful results. Joints only have so much range of motion when compressed, and perhaps just calculating angle differences in the joints is not enough to reveal actual changes that are present. Further studies looking at how riding ability affects the horse physiologically could be a valuable tool for managers when making horse usage decisions based on horse welfare. Findings in this area could allow horseman to become more aware of the effects riding has on horses' joints, which could assist in developing more sophisticated horse management plans.

While there was no difference in the behaviors defined in the ethogram of this study, a larger study with more controlled parameters could be warranted. There are existing data that correlate cortisol levels with stressful events that include riding. Examining salivary cortisol level differences between groups of riders could be a next step in determining how riding ability affects these lesson horses.

Riding lesson programs act as an entry point into the equine industry for thousands of people a year. These programs allow for lighter financial and time commitment by families who may otherwise be excluded from participation in the sport.

Given this, it is important to find better ways of managing and caring for the horses involved in these programs. Determining and reducing physiological and psychological stressors of lesson horses is important for the promotion of optimum health and longevity of use for this population of horse.

APPENDICES

APPENDIX A1: Rider Experience Assessment Tool

Participant Name ______________________________ Participant Age ________ Gender ______

Rider Influence on Horse Kinematics and Behavior

Rider Experience Assessment Instrument

Section 1

1. Have you ever ridden a horse before?

   ___ **Yes** (if yes, please identify length of time in years ______)
   ___ **No** (please proceed to Section 2)

2. Have you ever had formal riding instruction by an equine professional?

   ___ **Yes** (if yes, please identify length of time in years ______)
   ___ **No**

3. Have you ever competed in a horse show?

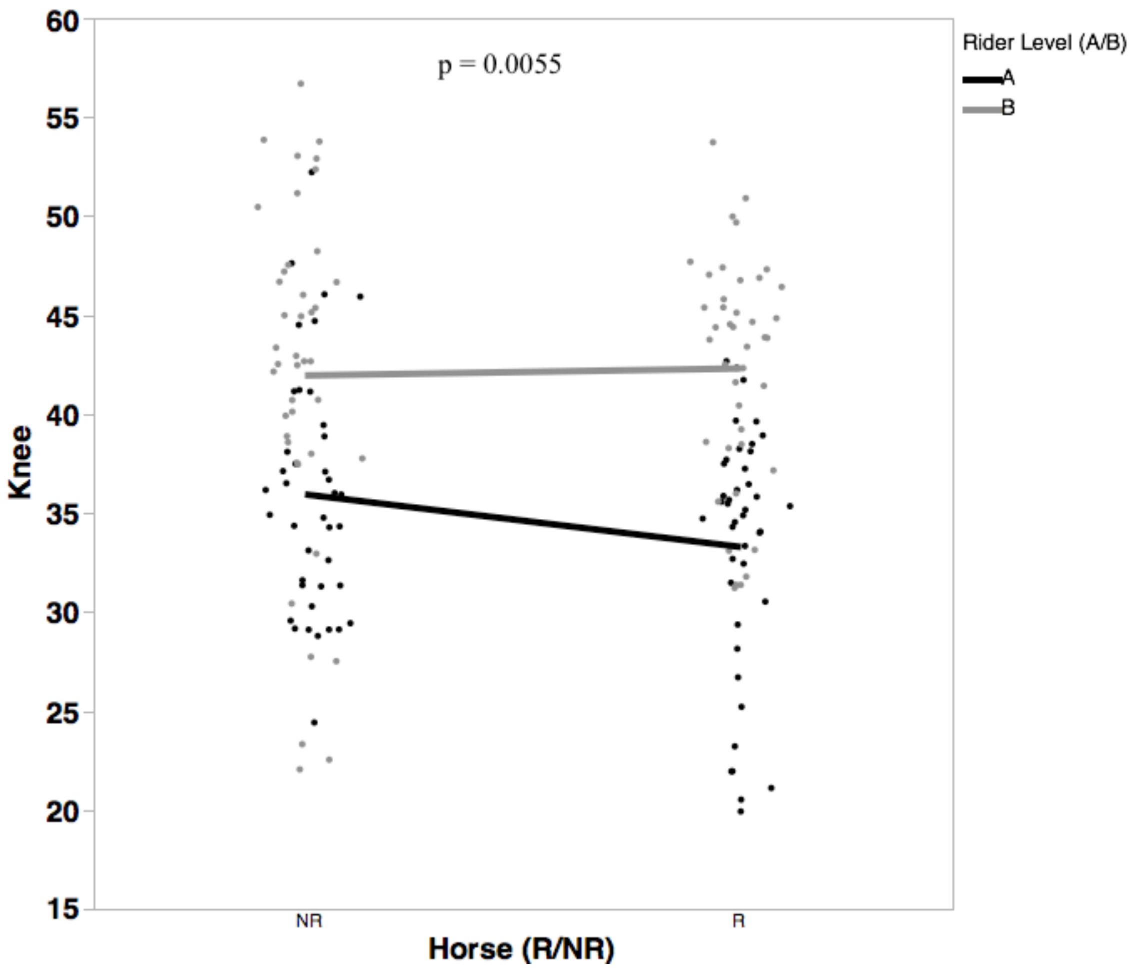
   ___ **Yes** (if yes, please indicate all types of classes shown)
   ___ walk/trot or go as you please
   ___ walk/trot/canter or Hunter Under Saddle/Pleasure or Western Pleasure
   ___ equitation/horsemanship classes (judged on rider)
   ___ IEA or IHSA classes
   ___ **No**

Section 2 – Riding Skills Development: *Please circle an appropriate response (1 = not competent, 2 = mildly competent, 3 = moderately competent, 4 = highly competent, 5 = mastery) for the specified riding skill and your perceived view on your current level of competency.*

	1	2	3	4	5
Halting on Horseback	①	②	③	④	⑤
Walking on Horseback	①	②	③	④	⑤
Trotting on Horseback	①	②	③	④	⑤
Cantering on Horseback	①	②	③	④	⑤
Steering Horses at the walk	①	②	③	④	⑤
Speed Control and Steering at the Trot	①	②	③	④	⑤
Speed Control and Steering at the Canter	①	②	③	④	⑤

APPENDIX A2: Rider Level Statistical Output

Differences in knee angle between advanced (A) and beginner (B) riders riding reactive (R) or non-reactive (NR) horses



WORKS CITED

Clayton HM. Horse Species Symposium: Biomechanics of the exercising horse 1. J. Anim. Sci. 2016; 94:4076.

Clayton HM. The dynamic horse: a biomechanical guide to equine movement and performance. Sport Horse Publications. 2004.

Clayton HM, Lanovaz JL, Schamhardt HC, Van Wessum R. The effects of a rider's mass on ground reaction forces and fetlock kinematics at the trot. Equine Vet. J. Suppl. 1999; 30: 218-221.

Dow S, Leendertz J, Silver I, Goodship A. Identification of subclinical tendon injury from ground reaction force analysis. Equine Vet. J. 1991; 23:266-272.

Eckardt F, Witte K. Kinematic analysis of the rider according to different skill levels in sitting trot and canter. J. Equine Vet. Sci. 2016; 39:51-57.

Ellis A, Stephenson M, Preece M, Harris P. A novel approach to systematically compare behavioral patterns between and within groups of horses. Applied Animal Behavior Science. 2014; 161:60-74.

Galisteo A, Cano M, Miro F, Vivo J, Morales J, Aguera E. Angular joint parameters in the Andalusian horse at walk, obtained by normal videography. J. Equine Vet Sci. 1996; 16:73-77.

Hamilton AG. Linear Algebra. Cambridge University Press. 1989.

Hall C, Kay R, Yarnell K. Assessing ridden horse behavior: Professional judgement and physiological measures. Journal of Veterinary Behavior. 2014; 9:22-29.

Hedrick T. Software techniques for two- and three-dimensional kinematic measurements of biological and biomimetic systems. Bioinspiration & Biomimetics. 2008; 3.

Hodgson DR, McKeever KH, McGowan CM. The Athletic Horse: Principles and Practice of Equine Sports Medicine. Elsevier/Saunders, 2014; 2013; 2004.

Kaiser L, Heleski C, Siegford J, Smith K. Stress-related behaviors among horses used in a therapeutic riding program. J. Am. Vet. Med. Assoc. 2006; 228:39-45.

Kang OD, Ryu YC, Ryew CC, Oh WY, Lee CE, Kang MS. Comparative analyses of rider position according to skill levels during walk and trot in Jeju horse. Human Movement Science. 2010; 29: 956-963.

Largarde J, Peham C, Licka T, Kelso J. Coordination dynamics of the horse-rider system. Journal of Motor Behavior. 2005; 37:418-424.

Merkens H, Schamhardt H, Vanosch G, Vandenbogert A. Ground reaction force patterns of dutch warmblood horses at normal trot. Equine Vet. J. 1993; 25:134-137.

Münz A, Eckardt F, Witte K. Horse-rider interaction in dressage riding. Human Movement Science. 2014; 33:227-237.

Peham C, Licka T, Kapaun M, Scheidl M. A new method to quantify harmony of the horse-rider system in dressage. Sports Engineering. 2001; 4:95-101.

Peham C, Licka T, Schobesberger H, Meschan E. Influence of the rider on the variability of the equine gait. Human Movement Science. 2004; 23:663-671.

Rietmann T, Stuart A, Bernasconi P, Stauffacher M, Auer J, Weishaupt M. Assessment of mental stress in warmblood horses: heart rate variability in comparison to heart rate and selected behavioral parameters. Applied Animal Behavior Science. 2004; 88:121-136.

Schils S, Greer N, Stoner L, Kobluk C. Kinematic analysis of the equestrian walk, posting trot and sitting trot. Human Movement Science. 1993; 12:693-712.

Weishaupt MA. Adaptation strategies of horses with lameness. Vet Clin. North Am Equine Prac. 2008; 24:79.

Weishaupt MA, Wiestner T, Hogg HP, Jordan P, Auer JA. Vertical ground reaction force-time histories of sound Warmblood horses trotting on a treadmill. The Veterinary Journal. 2004; 304–311.

Weishaupt MA, Hogg H, Wiestner T, Denoth J, Stussi E, Auer J. Instrumented treadmill for measuring vertical ground reaction forces in horses. Am. J. Vet. Res. 2002; 63:520-527.