The effects of increased shoe weight and decreased pastern angle on gain characteristics of the trot in one equine
by Nancy England Kingsbury

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Physical Education
Montana State University

Abstract:
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Analysis of the film footage was accomplished through a digitization process and the Filmdata software program. Temporal and linear stride characteristics, general limb kinematics and a two-dimensional illustration of the arc of the foot in flight were presented.

Increased shoe weight was associated with INCREASED duration of: diagonal dissociation at initial foot contact, diagonal swing, forefoot and hindfoot stance, bipedal support and suspension. Increased vertical displacement of forestep and hindstep, increased angular displacement and angular velocity of carpal, fetlock and pastern/coffin joints and decreased resultant linear velocity of the distal joints was also observed. The height of the first one-half of the flight of the foot was greater when the subject wore the heavier shoes. The heavier shoes were also associated with a DECREASED; swing duration, propulsion, and horizontal displacement of forestep and diagonal stride.

The shoe/pad combination was associated with INCREASED duration of forefoot and hindfoot swing, diagonal swing, hindfoot stance and suspension period. Increased vertical displacement of forefoot and hindfoot was also seen.

The shoe/pad was associated with DECREASED diagonal dissociation at initial foot contact, forefoot stance duration, duration of bipedal support, and horizontal displacement of forefoot and diagonal stride.

The methodology used in this study was successful in producing data that would allow the evaluation of changes in shoeing conditions on equine gait characteristics. This study presents a baseline evaluation of one equine subject's kinematical response to changes in shoeing conditions. It is a presentation that has, in the researcher's opinion, great potential for use as a starting point for future research projects.

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Nancy England Kingsbury

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

1/3/89 — Date

Ellen Kingsbury — Chairperson, Graduate Committee

Approved for the Major Department

3 January 1989 — Date

Head, Major Department

Approved for the College of Graduate Studies

January 17, 1989 — Date

Henry L Parsons — Graduate Dean

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ABSTRACT

The initial objective of this study was to develop a filming technique that would produce film footage that would allow accurate biokinematical analysis of equine gait. One horse of normal conformation was selected as the subject for this study. Anatomical landmarks were identified and demarcated on the left forelimb of the subject. The subject was first filmed moving at an extended trot in a balanced/barefoot state. The subject was then filmed while wearing balanced/8-ounce, balanced/16-ounce, 8-ounce/3 degree pad and 16-ounce/3 degree pad.

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The shoe/pad was associated with DECREASED diagonal dissociation at initial foot contact, forefoot stance duration, duration of bipedal support, and horizontal displacement of forefoot and diagonal stride.

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CHAPTER 1

INTRODUCTION

The scientific investigation of the functional anatomy of the equine foot did not begin until the 18th century. Largely due to the lack of more sophisticated instruments, the early studies were based primarily on cadavar dissections. These studies proved helpful to practioners attempting to identify pathologies of the equine foot and standardize methods of treatment.

During the early 20th century, the advent of the automobile and tractor virtually eliminated the horse as an American necessity. Scientific research on equines, the field of farriery in particular, was no longer in such high demand. However, increased leisure time and the legalization of parimutual betting rejuvenated the equine industry during the post-World War II years. As horse racing became one of the largest spectator sports in the nation, the equine athlete increased steadily in popularity and value.

Encouragement in the form of financial support from equine enthusiasts provided an incentive for the investigation of scientific areas related to equine movement such as biomechanics, physiology of exercise, and equine sports medicine. Electrogoniometry and high-speed cinamatography were adapted to the equine subject and the needs of the equine researcher.

During the last two decades, researchers have become increasingly interested in the potential of high-speed cinematography in the study of equine gait. Specific areas of interest include the effects of fatique on gait and gait adaptations to race track design.

One important aspect of interest that remains relatively uninvestigated is the study of farriery conditions and the effect of the horseshoe on equine gait pattersn. Whether the subject is a race horse, polo pony, barrel racer or show horse, one common denominator among successful equine athletes is the horseshoe.

Horseshoeing has long been considered a necessary evil in the world of the working equine athlete. The type of horseshoe worn by an individual equine depends on factors such as his unique gait pattern or the style of action desired by his trainer. The specific effects of a change in horseshoe condition are often measured simply by the discretionary eye of a farrier or the hands of the stopwatch.

Many assumptions based on common sense and trial and error have been handed down from one generation of farriers to the next. Disagreements and contradictions in terminology and methodology are an expected obstacle in the study of the science of horseshoeing.

The effects of increased weight on gait pattern or style is an area that remains relatively uninvestigated. Although an increase in the weight of the horseshoe is thought to change the action of the foot in flight, to this researcher's knowledge the assumption has not been objectively substantiated.

A study that would provide baseline information as to the effects of the basic horseshoe might assist practitioners in the objective evaluation of common farriery techniques. The following study was designed to provide baseline data for future research on the effects of various horseshoe conditions of equine gait. Quantitative and qualitative measurements of angular and linear variations in the coordinative movements and style of gait due to increased shoe weight and decreased pastern angle were the desired end-results.

One challenging problem of the study was to develop a cinematographic technique that would allow collection of sufficient data for the investigation of changes in equine gait mechanics as affected by variation in shoeing conditions.

Statement of the Problem

The general purpose of the study was to identify and describe the kinematics of the equine limbs with changes in horseshoe weight and pastern angle. Specific problems were:

1. to identify and describe changes in temporal characteristics of a diagonal pair of limbs during a symmetrical two-beat gait;
2. to identify and describe changes in linear characteristics of a diagonal pair of limbs during a symmetrical two-beat gait;
3. to describe general kinematics including angular displacement and angular velocity of, and linear velocity the carpal, fetlock, anterior and posterior pastern/coffin joints of the forelimb measured in the sagittal plane; and

4. to illustrate the changes in the arc of the foot, during its trajectory of flight in the sagittal plane.

Delimitations

The study was delimited to one, four-year-old grade quarter horse gelding in Bozeman, Montana. The subject was of normal conformation. The subject was not chosen to be representative of all horses nor even the Quarter Horse breed, but simply one equine's response to specific horseshoeing conditions.

Limitations

The study was limited to the use of a single normal subject. There was no control over the method of foot care and trimming previous to the study.

To the author's knowledge, there was no available information as to the length of time necessary for the equine to adapt to horseshoeing changes. During the study, an adaptation period of approximately five minutes was allowed prior to each test run.

An experienced farrier was used throughout the study. His ability to perform with consistent competence was an accepted limitation.

Due to the unavailability of a specialized equine treadmill, the speed of the subject during the trials was regulated soley by use of an automobile. Therefore, the study was limited to the reproduction of consistent speed by the driver of the automobile and the precision of the odometer.

Definition of Terms

ARC OF FOOT FLIGHT - The curvilinear path of the foot from the moment of toe-off to the moment of foot contact with ground surface as described by the marker on the lateral tip of the toe.

BALANCED FOOT - The ground surface of the foot is perpendicular to the longitudinal axis of the foot (Butler, 1976).

BIPEDAL SUPPORT - The time during which the two diagonal hooves are in contact with the ground (Drevemo, Fredricson, Dalin and Bjorne 1980b).

BREAKOVER - The period of time from initial hoof contact to toe-off (Butler, 1976).

DIAGONAL DISSOCIATION - The forelimb and the diagonal hindlimb do not touch the ground or take off simultaneously at the trot (Drevemo, et al; 1980b).

DIAGONAL LENGTH - The distance in the x-direction of one diagonal stride, including the linear displacement of both diagonal limbs as measured from the toe of the hindfoot to the toe of the diagonal forefoot.

DIAGONAL SWING - The period of time, during a diagonal stride, from the moment when one limb of the diagonal pair toes-off to the initial hoof contact of one of the same diagonal pair (Fredricson, and Drevemo; 1972a).

GAIT - A cylical pattern of movement that is repetitive in sequence and timing (Hildebrand, 1965).

KINEMATICS - The study of the temporal and spatial motion of a system (Kreighbaum & Barthels, 1985).

MID-STANCE - The position during stance phase when the carpus or tarsus (forelimb or hindlimb, respectively) is in vertical position (Fredricson, et al; 1972a; Pratt & O'Connor, 1977).

PROPULSION - The stage of stance support lasting from mid-stance until toe-off (Fredricson, et al; 1972a; Pratt & O'Connor, 1977).

RESTRAINT - The stage of stance support lasting from initial foot contact with ground surface until mid-stance occurs (Fredricson, et al; 1972a; Pratt & O'Connor, 1977).

SKILL - when a general pattern of movement is adapted to the constraints of a particular activity (Kreighbaum & Barthels, 1985).

STANCE - The period of time during a stride when the foot is in contact with the ground (Fredricson, et al; 1972a; Drevemo, Dalin, Fredicson and Hjerten; 1980a).

STEP - The horizontal displacement of the limb, from toe-off to heel-touch.

STEP HEIGHT - The vertical displacement of the foot, from toe-off to the height of the swing, as measured by the tip of the toe.

STRIDE DURATION - The time of one complete gait cycle; i.e. the time interval between any two identical events of a cycle (Hildebrand, 1965).

STYLE - The use of individual modifications, such as unique timing or movements, within the parameters of a given technique (Kreighbaum & Barthels, 1985).

SUSPENSION PHASE - The period of time during which the horse has no physical contact with the ground surface (Gray, 1968).

SWING - The period of time, during a stride, when the foot has no contact with the ground surface (Fredricson, et al. 1972a).

TECHNIQUE - A particular way of performing the same skill (Kreighbaum & Barthels, 1985).

CHAPTER 2

REVIEW OF LITERATURE

The advent of the multi-million dollar racehorse is a reflection of the overall increase in value of all breeds of equine athletes. Therefore, it is not surprising that equine trainers have become increasingly interested in research that suggests more effective means of training, conditioning and outfitting that might promote improved racing, show ring, or other performance.

The following review of literature represents a review of research that was considered by the author to be relevant to the present study. The literature is presented under the topics of general equine locomotion, specific horseshoeing conditions and equine limb kinematics.

General Equine Locomotion

Equine locomotion is generally described in terms of gait. The aesthetic appearance of a specific gait may often vary according to factors such as breed, style and training. For example, the trot is defined as a symmetrical, two-beat diagonal gait, yet there appears to be little similarity between the streamlined racing trot of the Standardbred and the animated part trot of the Saddlebred or Morgan.

Although the trot is a skill innate to most horses regardless of breed, training and heredity account for the development of a specific technique that is desireable for the situation. The individual equine athlete also develops its own unique style, modifying the technique due to anatomical limitations or an altered sense of timing.

Regardless of technique or style, horses travel in specific gaits. Historically, the study of equine locomotion has been plagued with confusing variations in terminology for specific components of those gaits (Leach & Dagg, 1983).

In a study of the gaits of the horse, Hildebrand (1965) described a stride as one full cylce of motion. The limbs move in rhythmic pendulum-like motion in a sagittal plane. Because the sequence of movement is diligently repetitive, any point in the pattern may be designated as the beginning of a stride (Hildebrand, 1965; Gray, 1968).

The two main parts of a stride are the SUPPORT phase, wherein the hoof is in contact with the ground, and the SWING phase, wherein the hoof travels through the air (Pratt & O'Connor, 1978). Gray (1968) stated that the length of the swing phase varies inversely with the length of the support phase, that is, the shorter the period of support, the longer the period of swing. Gray (1968) illustrated that theory with the examination of an equine subject's change in gait from a walk to a fast trot. During the transition from walk to trot, the equine demonstrated three changes in limb movement:

1. The frequency of limb movement increased.
2. The duration of the support phase decreased.

3. Gait pattern changed from a four-beat gait at the walk to a two-beat diagonal relationship between a forelimb and contralateral hind limb at the trot.

The trot is therefore referred to as a diagonal two-beat, gait. The diagonal may be described as right or left, according to which forelimb is in the swing phase.

When the diagonal pairs are perfectly coordinated, the body is supported by alternating diagonal pairs of limbs with intervening periods when all feet are off the ground (Gray, 1968). The period of time when two legs, a single diagonal pair, support the full weight of the body is called OVERLAP, (Pratt & O'Connor, 1976) or BIPEDAL SUPPORT (Drevemo, Fredricson, Dalin, and Bjorne, 1980b).

Several authors have attempted to describe the phases of the stride using a variety of terminology. Adams (1971) divided an individual stride into anterior and posterior phases. The ANTERIOR phase was the portion of the stride that occurred in front of the print of the opposite foot. That half of the stride that occurred in back of the opposite foot print was said to be the POSTERIOR phase.

Gary (1968) also divided the stride into two phases. Any forward displacement of the limb, relative to shoulder (forelimb) or hip (hindlimb), was identified as PROTRACTION; any backward displacement of the limb, relative to the shoulder or hip, was identified as RETRACTION.

Pratt and O'Connor (1976) recongized the swing phase but chose to identify the support phase as a STANCE period. The stance phase ended at TOE-OFF, which was preceded by HEEL-OFF. BREAKOVER time was the interval from heel-off to toe-off.

Grogan (1951) identified the period of time when the hoof was on the ground as the CONTACT period. The FLIGHT period was when the hoof was off the ground.

Pratt and O'Connor (1976) further divided the stance phase by defining the MIDSTANCE position. In the forelimb, midstance occurs when the metacarpus is vertical to the ground. The midstance signifies a change in the horizontal component of hoof-ground interaction. A DECELERATION phase occurs from initial hoof contact to midstance; and a PROPULSION phase occurs from midstance to liftoff.

Specific Horseshoeing Conditions

In the world of the working equine athlete, horseshoeing has long been considered a necessary evil. Variations in environment and surface conditions may accelerate the natural wearing of the hoof wall, causing uneven breaking and detrimental cracking. The application of horseshoes provides an artificial barrier effectively preventing most hoof wall breakage.

There is a trade-off, however. The steel horseshoe greatly limits the natural expansion and compression of the frog, effectively decreasing the venous "pumping" of blood through the hoof structures and back up the equine limb (Adams, 1971). Therefore, the ideal horseshoe should interfere as little as possible with the natural physiological function of the equine foot, yet still accomplish the protective purpose of the shoe's application.

According to the War Department (1941) the design and fit of the individual horseshoe affects not only the position of the foot at breakover, but also the speed of breakover and the flight of the foot during the swing phase.

Within the show ring world of the Tennessee Walking Horse, Morgan, and the American Saddlebred, one common horseshoeing characteristic that may vary a great deal is that of weight. An increase in horseshoe weight is thought to increase the height of the step and the length (horizontal distance) of the stride, (Butler, 1976; Adams, 1971) as well as promote a "knee-snapping" action, a trait desireable in the animated show trot of the best saddle and fine harness horses. Weight may also be added to the forefeet of the racing trotter who habitually breaks from a trot to a gallop in an attempt to stabilize the timing of the diagonal limbs and balance them at speed (Butler, 1976).

It would be a logical assumption to expect that increased horseshoe weight would also cause an increase in fatigue of the performance horse. Thus, the sixteen ounce toe-weight shoe of the saddle horse might indeed prove disastrous to the Thoroughbred race horse.

Weight may be evenly distributed throughout the horseshoe or the shoe may be toe-weighted or heel-weighted. According to Butler (1976), the application of toe-weighted shoes will result in increased action of the forequarters, as well as increase the height of the last one-half of an individual stride. A heel-weighted shoe would increase the height of the first one-half of an individual stride.

The pastern-coffin joint angle, as measured by a hoof protractor, is another factor that influences the speed of breakover and the pattern of the foot in flight. The pastern-coffin joint angle may be temporarily increased or decreased with the addition of a 3-degree pad. Usually made of neoprene, the pad is sandwiched between the horseshoe and the sole of the hoof. The pad may be used to either elevate the heel or the toe, depending upon which way the wedge is fitted. The pad is commonly used to correct faulty conformation or simply to protect the sole of the hoof (Simpson, 1971).

According to Butler (1976), the normal range for the pastern-coffin joint angle in the equine forelimb is approximately 45 to 55 degrees. A steeper angle results in a quicker breakover of the foot, increased vertical height of the step and decreased length of stride arc. Conversely, lowering the heels and thereby decreasing the pastern angle would result in a slower breakover of the foot, decreased height, and increased length of stride (Butler, 1976; Simpson, 1971).

To the author's knowledge, Nilsson (1973) is the only researcher to use high-speed cinematography to investigate the influence of alteration of horseshoeing conditions. The conditions investigated were the effects of the application of toe grabs and heel caulks on equine limb kinematics.

The purpose of the application of toe-grabs is to increase the maximum pastern/coffin joint angle at heel-off, which would result in increased tension of the deep flexor tendon and an increase in pressure on the navicular (distal sesmoid) bone. Heel caulks elevate the heel, causing a reduction of the maximum pastern/coffin joint angle, facilitating heel-off (Nilsson, 1973).

Nilsson (1973) conducted intraindividual comparisons using ten Standardbred trotters. The subjects were filmed at a slow trot with no implements applied, again with toe-grabs, and once more with heel caulks. Without the provocative agents, the height of the step of the foreleg was consistently higher than in the contralateral hindleg. The application of toe-grabs and heel caulks did not noticeably alter step height or change the amount of foot slide during ground contact. According to Nilsson (1973), the toe-grabs did cause the pastern/coffin joint angle at heel-off to be greater in both front and hindlegs. Conversely, the heel caulks reduced that same angle in both front and hindlegs.

Dalin, Drevemo, Fredricson, Jonsson, and Nilsson (1973) utilized high speed cinematography for analyzing locomotor asymmetry of horses trotting through turns. While trotting at racing speed, some horses travel in a LINE-GAIT, that is, due to the adduction of the distal part of the limbs, the diagonal hooves (foreleg and contralateral hindleg) are usually placed close to or on the line of motion. The line of motion represents the projection of the horse's mid-sagittal plane on the track. Crossing the sagittal line of motion is a condition identified as OVERCROSSING.

INWARD INCLINATION is a technique used when the horse leans into a turn at racing speed. The line-gait becomes more or less pronounced, depending on the amount of adduction of extremities. A variety of lower leg alignments seem to stem from the subject's body position. As seen from the front, the carpus may seem to medially deviate, resulting in a varus positioning of the fetlock. The contact pattern of the hoof is also affected. At the moment of initial hoof contact with the track surface, the subject may exhibit a lateral heel contact, with the outside edge of the hoof touching first and then rolling inward to the flat foot position (Dalin, et al. 1973).

Limb Kinematics

Electrogoniometry was used to measure the angular displacement of the joints of the equine leg by Taylor, Tipton, Adrian and Karpovich (1966). The goniogram provided a permanent record of joint angulation during locomotion. The goniograms were recorded for the walk (3 mph) and the trot (6 mph) of the normal equine subject. Specific joints of interest were the metacarpophalangeal (fetlock) joint and the carpal joint of the forelimb. The following characteristics were observed:

1. The standing fetlock angle was determined to be 210 degrees, as measured posteriorly. At a walk, movement at the fetlock joint ranged from 201 degrees at hoof contact, to 188 degrees at hoof lift, continuing to a maximum 182

degrees of flexion during forward swing. At a trot, the range of movement was increased by 65 percent.

2. The standing angle for the carpus was 180 degrees. The range of motion at the walk was 123 to 182 degrees. The greatest amount of flexion occurred during the swing phase. At the trot, an increase from 116 to 186 degrees was evident.

3. During both walk and trot, flexion of the fetlock joint was faster than extension. The reverse was true in the carpal joint.

The supposition that increased linear speed of gait resulted in increased velocity and magnitude of joint angulation was supported by Adrian, Grant, Ratzlaff, Ray, and Boulton (1977). In that study, four mature Thoroughbreds (ages 5 to 9 years) were used as subjects. One of the animals, chosen to be the control subject, was examined clinically and radiographically and determined to be of "normal" conformation. Three of the horses were selected as subjects on the basis of having symptomatic pathologic change in the metacarpophalangeal joint of one forelimb.

The effects of fetlock joint lameness on forelimb kinematics were measured electrogoniometrically. The goniograms of the three clinically lame horses indicated a decreased amount of fetlock joint flexion, as compared with the subject's own normal fetlock, as well as the control subject. The differences in range of motion in all subjects increased with a corresponding increase in speed from walk to trot.

In order to analyze the kinematics of fast-moving Standardbred trotters, Fredricson and Drevemo (1972a) adapted a computerized three-dimensional analysis program that was originally developed for testing prototype aircraft during flight. The three-dimensional analysis program was used to identify attitude angles of the hoof, specifically PITCH, YAW and ROLL. The HOOF PITCH identified the movement of the hoof around its frontal axis. YAW movements occurred around the hoof's longitudinal axis. The ROLL of the hoof occurred around its sagittal axis.

The RESULTANT JOINT COORDINATION PATTERN (RJCP), which consists of pitch, yaw and roll components, is a three-dimensional illustration of hoof movement. The spatial orientation of the hoof could be considered to result from the movement of the forelimb's articulations and may be considered to reflect that extremity's coordinated joint movements (Fredricson, et al. 1972a).

The hoof trajectory, when filmed from a lateral view, presented a two-dimensional pattern. The two-dimensional RJCP was compared with the three-dimensional RJCP for one stride of the right forelimb of each of the ten test subjects. The results showed strong agreement between the three-dimensional and two-dimensional RJCP's of each subject. Fredricson, et al (1972a) suggested that two-dimensional analysis was a suitable choice for future researchers who desired to measure hoof trajectory during flight.

Fredricson and Drevemo (1972c) suggested that the equine subject possesses a very consistent pattern of locomotion. A schematic two-dimensional RJCP was graphically presented, identifying minimal and maximal angulations during the swing phase of each stride. Contralateral strides and consecutive strides were shown to be highly consistent in pattern. Such consistency prompted the researchers to theorize that analysis of a single stride would be sufficient in future studies of equine locomotion.

Duration of support and swing phases of consecutive strides of the forelimb and hindlimb varied minimally. There was minimal variation in the duration of both phases, when comparing forelimb to contralateral and ipsilateral hindlimb (Fredricson et al., 1972c).

The description of forelimb joint kinematics in Standardbreds traveling at a racing trot by Fredricson and Drevemo (1972c) shows that not only does the equine seem to have minimal linear displacement variations among strides, it also has very consistent joint angulation patterns. When comparing the values of the angles of consecutive forestrides of each individual equine subject, the fetlock, carpal and elbow joints exhibited minimal variation from one stride to the next. The greatest variation was seen in the pastern/coffin joint, where differences in angulation of consecutive strides were as high as ten degrees. The researchers suggested that one possible explanation for such angular variation was the subject's attempt to react to the minor variations inherent to the racetrack surface.

Previous studies have shown that fast-moving Standardbreds have remarkable consistency in locomotion (Drevemo, Dalin, Fredricson and Bjorne, 1980c; and Fredricson and Drevemo, 1972a, c). Such stability suggests a finely-tuned timing process within the central nervous system of the equine allowing consistent coordination between the limbs moving at racing speed.

Drevemo, Fredricson, Dalin and Bjorne (1980b) sought to analyze the ability of the horse to maintain constant rhythmic control during the racing trot. Results of the analysis of the coordination between the limbs of fast-moving Standardbreds were the following:

1. The mean duration of the right fore- and hindsteps was 225 msecs. The mean duration of the left fore-and hindsteps was 229 and 230 msecs. The right and left foresteps measured 273 and 272 cm, while the right and left hindsteps measured 270 and 275 cm, respectively.
2. The overall mean duration for bipedal support was 99 msecs for both diagonals. The diagonal length was 105 cm for the left diagonal and 102 cm for the right.
3. The overreach duration is the time interval from the event when one forehoof leaves the ground to the movement when the ipsilateral hindhoof touches it. The overall mean overreach duration was 123 msecs on the left side and 119 msecs on the right.
4. The suspension period represents the time period when the horse has no contact with ground surface. The mean duration of the left and right suspension was 99 msecs. Sixty-six percent of the horses showed differences between right and left suspension periods, indicating that a horse may have a stronger or weaker diagonal.

Drevemo, Dalin, Fredricson and Bjorne (1980c) supported Fredricson and Drevemo's (1972a) statement regarding the horse's ability to maintain consistent gait patterns. Twenty-two horses were filmed twice during the same day, under the same conditions, at the same gait. The subject's ability to maintain short-term reproductibility of length of stride, and duration of: stride, stance, swing, propulsion, diagonal dissociation at landing, step and suspension, were shown to have little variation ($p < 0.05$) using Students t test.

Drevemo, Dalin, Fredricson and Hjerten (1980a) established several linear stride characteristics using the methodology established by Fredricson and Drevemo (1972b). The following characteristics were found to be demonstrated by 30 clinically sound Standardbreds trotting at racing speed:

1. The overall mean stride length was 545 cm.
2. The overall mean lengths of strides ranged from 488 to 607 cm. The differences were explained by the variation in height and limb lengths.
3. The overall mean stride duration was 455 msecs.
4. The stance phase lasted from the moment of heel contact until the moment toe-off occurred. The stance phase duration was somewhat longer in the hindlimbs than in the forelimbs.
5. The stance phase was subdivided into DECELERATION and PROPULSION stages. The deceleration phase, although somewhat longer in the hindlimbs than the forelimbs,

represented 40 to 45 percent of the stance phase. The propulsion stage durations, 64.3 to 67 msecs in length were equal in all limbs.

6. The swing phase was begun the moment the foot was lifted from the ground. Of the total duration of a stride, 25% corresponded to the stance phase while 75% was said to be swing phase.

Fredricson, Drevemo, Dalin, Hjerten, Bjorne and Rynde (1983) described the development of a treadmill specially designed to accommodate the exercising and controlled testing of equine subjects. Such an instrument may represent a breakthrough in the analysis of equine locomotion as well as other areas of interest such as equine exercise physiology. The equine treadmill could be inclined as much as 10 degrees longitudinally and 7.5 degrees transversely and accommodate a horse running at racing speed.

Fredricson, et al. (1983) reported the test results of a Standardbred trotter filmed while trotting on a treadmill and then on a racetrack. In a comparison of gait patterns, at a consistent speed, only minor differences in stance phase and limb synchronization within individual strides was noted. However, the swing phase duration, as well as stride and step length, were significantly shorter ($p < 0.001$) and had a higher frequency on the treadmill as compared with the gait pattern on the racetrack.

Summary

Equine locomotion is commonly described in terms of specific gaits. Regardless of the degree of animation, the trot is a gait that may be identified by its symmetrical two-beat diagonal movement.

A problem commonly encountered when attempting to interpet previous research in equine locomotion is that of confusing variation in terminology for the components of a gait pattern. This apparent lack of standardization creates confusion for those attempting to understand the terminology describing equine locomotion.

For instance, the period of time when an individual leg supports the animal's bodyweight may be called the stance, contact, support or breakover period. This phase may be further divided into initial hoof contact, deceleration phase, mid-stance, propulsion, heel-off and ending with toe-off, or lift-off.

An individual stride may be divided into an anterior or posterior phase, and/or a protraction/retraction phase. The period of time when the hoof travels through the air may be called a swing or flight phase. In the trot, when the body is supported by a diagonal pair (forelimb and contralateral hindlimb) it may be termed to be bipedal support or overlap.

Many of the theories concerning cause-effect of common horseshoeing techniques have simply been handed down from one generation of farriers to the next. For instance, it is a common technique, among trainers of fine show horses, to increase horseshoe weight in order to produce a 'knee-snapping' action on their fine show horses. Although a factor such as increased horseshoe weight was thought to increase the height and length of an individual stride, to the researcher's knowledge, the kinematical evaluation of those effects, or others, has not previously been attempted.

Much of the previous research using high-speed cinamatography have used Standardbred trotters traveling at racing speed. These studies have produced a great deal of valuable data supporting the theory that the equine moves in a very consistent gait pattern and that it is possible to achieve valid results while analyzing a single stride of a particular subject. Filming technique and the establishment of aspects for analysis were also valuable contributions of these earlier studies.

These studies, however, utilized a great deal of highly-specialized equipment including a camera car and a smoothly groomed oval racing track. The further development of a heavy-duty treadmill equipped specially for the needs of the equine subject was a significant breakthrough. Although costly to purchase and maintain, this piece of equipment would allow indoor filming, eliminating the effect of inclement weather and unreliable lighting conditions.

This review of literature presented previous research in the catagories of equine locomotion, specific horseshoeing conditions, and equine limb kinamatics. The researcher attempts to illustrate the general lack of standardization of terminology within the study of equine locomotion as well as the lack of objective analysis of common horseshoeing conditions. Also presented were several previous studies utilizing accepted methodology of high-speed cinematography and analysis of equine gait.

CHAPTER 3

METHODS AND PROCEDURES

Data collection methods were based on techniques described in previous studies and from knowledge gained from the pilot study. The desired end-results of this study were 1) quantitative descriptions of limb kinematics, as induced by increased horseshoe weight, and 2) qualitative assessments of variations in gait kinematics as induced by a) increased shoe weight and b) decreased pastern/coffin joint angle.

Subject Description

The subject was a four-year old, bay grade Quarter Horse gelding. The subject was selected partly because of its dark bay color and lack of white leg markings that might blend in with the background. The subject was of normal conformation with no obvious deformities and was determined by an experienced equine veterinarian to be clinically sound.

Anatomical Landmarks

Lateral View

Previous to the filming session, anatomical landmarks were selected and reference points marked. Each landmark was identified and palpated by an experienced equine anatomist, and are shown in Figure 1. Specific landmarks were:

1. Distal lateral epiphysis of radius
2. Proximal lateral splint bone
3. Distal lateral metacarpal bone, anterior to proximal sesmoid
4. Distal lateral P-1 (1st phalanx)
5. Posterior-lateral hoof wall, distal to heel bulb
6. Anterior hoof wall, distal lateral tip of toe

The hair over the area was closely shaven. A piece of approximately two-inch square white surgical adhesive tape was attached directly to the skin over the landmark area. An orange 3/4-inch diameter round adhesive sticker was attached to the white tape square, directly over the palpable landmark.

Shoeing Conditions

The subject was orginally filmed in a balanced barefoot condition. The balancing of all limbs was accomplished by an experienced farrier. A hoof protractor was used to measure the pastern angle. The pastern angle of the right forelimb was 52 degrees and the left was 51 degrees (see Figure 2).

Toe length was measured using a conventional measuring tape. In the barefoot condition, the toe length was 3 1/2 inches from the tip of the toe to the proximal edge of the hoof wall. A maximum toe length of 4 3/4 inches was measured upon the application of the neoprene pad with the sixteen ounce plate.