CHANGES IN SWINE GAIT OVER TIME RELATED TO GROWTH, SOUNDNESS, OR TRIMMING

by

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(Under the Direction of C. Robert Dove)

ABSTRACT

Gait analysis is a common method to obtain quantitative measures of movement. In pigs, it is unknown how much training to the mat is needed to provide quality gait data. In the first study, thirty-three, 68 kg grower pigs were used to study the effect of a week of training on gait parameters. The results of this study showed that while improvement occurred during the week, the weekend was long enough for the pigs to regress in their training. The studies of gait in swine have been limited to studying lameness. Studies are also needed to look at how sound animals move to set parameters that are desired for gait quality. In the second study, thirty-three pigs were recorded every 23 kg from 23 kg to 136 kg to observe if any parameters are predictive across the weights. None of the parameters were maintained, but swing was closest to being steady, which reflects what is seen in horses. Functional trimming has been shown to be beneficial to sow gait qualities. Blunt trimming has not been studied, even though it is easier to perform than functional trimming. In the third study, blunt and functional trimming were compared on nineteen sows to see if the benefits of functional trimming can be seen with blunt trimming. In the end, blunt trimming did not provide the improvements that functional trimming does, but trimming dewclaws did seem to provide some benefits to the sow's gait quality. Another method of preventing lameness is to feed minerals to strengthen claws from the inside. Organic minerals have been shown to have a higher absorption and retention compared to inorganic minerals. In the final study, 70 gilts were spilt into two groups, with one group being the control and the other receiving a supplementation of amino acid mineral-complex from nursery through the second parity. During both gestations, the sows were brought in and gait analysis was performed along with measurements of claw and dewclaw lengths. Production data was collected for both parities. The amino acid mineral-complex was shown to benefit sows by preventing gait changes that occurred between first and second parity.

INDEX WORDS: Swine, Gait Analysis, Lameness, Preventative, Amino Acid Mineral-Complex

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DEDICATION

I would like to dedicate my dissertation to Gray, my other half in the canoe. Thanks for battening down that hatches when I lose my paddle.

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CHAPTER 1

Introduction

Gait analysis has been shown to be an objective tool compared to traditional systems of lameness scoring, which are highly subjective with varying degrees of inter- and intra-observer correlation (Mohling et al., 2014). Gait analysis is an important tool to consider when trying to provide quantitative data for changes in gait quality. The systems that are used allow for less user error due to less control going to the user to define measurements. Using gait analysis verses subjective methods of classification is more successful in targeting longevity characteristics and preventing lameness (Stavrakakis et al., 2014). This analysis provides solid numbers that have very low user error involved, especially when compared to lameness scores. It has been shown that using gait analysis parameters detect pigs with abnormalities which are not observed by visual observation (Stavrakakis et al., 2014)

In pigs, it is unknown how much training is needed to provide reliable gait analysis data. In cattle behavior differences are thought to be a reflection of temperament and can cause biomechanical differences in gait presentation(Broucek et al., 2013a; Broucek et al., 2013b). Therefore, causes of temperament differences need to be looked into to see their effects on gait. Another unknown is if there are any gait parameters that could be used in young pigs to predict locomotor function later in life. By using gait analysis, it is also possible to track preventive treatments over an extended period of time to see the long or short term effects such treatments may have on the pigs. For these studies, the focus was on not only the gait analysis but also on lameness. Lameness has become one of the leading causes of culling within the swine industry. This issue has only grown since sows have been put into group housing. Ways to solve lameness include trimming sow's claws and dewclaws or providing the sows with minerals to support healthy claw growth. The following studies will look out these issues and hopefully provide some ideas on answers to these problems.

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CHAPTER 2

Literary Review

Lameness

Lameness is a major factor for welfare because of high prevalence and debilitating effects (Bicalho and Oikonomou, 2013). When lame, the sow will have behavioral changes due to physically reduced locomotor ability, pain, or general discomfort and sickness behavior (Heinonen et al., 2013). These changes have a direct impact on the sow's welfare. Even when given analgesics, animals can still show some level of lameness, which shows that lameness can be multi-faceted in nature (Weary et al., 2009). Lameness can be related to locomotion disturbances, leg weakness, joint disorders and claw disorders (Thorup et al., 2007). These conditions are compounded by each other and can lead to larger lameness problems. Causes for lameness can be non-infectious, such as osteochondritis, degeneration of cartilage and bone in young animals, and limb malformation, or infections such as joint arthritis or infected skin lesions (Traulsen et al., 2016).

Risk factors for lameness include age at breeding, current age or parity, claw lesions or claw infections (Weary et al., 2009). The lame sow is expected to have a reduction in activity level, social and explorative behavior, and feeding behavior (Heinonen et al., 2013). These activity changes challenge the freedoms of the sow. It has been shown that sows that are lame have significantly lower daily water intake than sound sows (Heinonen et al., 2013). This decrease causes a drop in the reproduction efficiency of the sow, which is unable to compete with healthy-legged sows for food and water

(Heinonen et al., 2013). Because of the negative impact on productivity, lameness is one of the major welfare indicators of the herd (Bicalho and Oikonomou, 2013; Cador et al., 2014; Lisgara et al., 2015). Reduction of longevity and number of piglets born every year can be traced back to the increased culling rates due to lameness (Lisgara et al., 2015). Sows that are lame are removed at an earlier age than those culled for other reasons, which leads to removal before the maximum litter size is reached (Anil et al., 2005). This leads to a smaller average litter size for the herd, which negatively impacts the cost of production. This makes lameness not only a welfare issue, but also a major source of revenue loss within pig production (Le et al., 2015).

Overall there are significant differences between survival rates of lame and non-lame sows in a commercial herd (Anil et al., 2009). The significant difference in survival rates reflects the high cull and early euthanasia rates that are associated with lame sows. Being able to keep a sow sound allows her to be productive and healthy within the herd for a longer period of time. Culled gilts and first parity sows have a greater rate of being removed due to lameness compared to all other reasons (Anil et al., 2005). There is a need to minimize the incidence of lameness and to remove lame sows from the herd as early as possible when treatment and recovery is not an option (Anil et al., 2005; Anil et al., 2009). Early removal of lame animals increases the value and welfare of the herd.

Lameness is a major issue that has been shown to be the second major cause of culling within a sow herd (Devillers and Conte, 2012). Culling resulting from lameness causes strain on the production herd to replace the sows. Some sows that are culled for reproductive reasons can trace their problem back to lameness (Abell et al., 2014). Thus, the total impact of lameness on the industry economy is unknown. There is also long term economic loss with keeping a lame sow in the herd. Sows that are lame may stay in the herd due to being late in gestation, or their lameness may be less pronounced at weaning due to reduction in body weight during lactation (Anil et al., 2009). This allows sows that are predisposition to lameness to pass on the predisposition to their offspring.

Within the replacement herd, lameness is an important criterion in gilt selection and accounts for up to 25% of culling reasons in gilts (Devillers and Conte, 2012). Lameness therefore has a major economic impact on the swine industry. When looking at culled sows, 85%of the sows postmortem had at least one superficial lesion on at least one claw (Abell et al., 2014). Such a high incidence of lesions creates a negative impact on the economic production of the farm. Herds with a high prevalence of lameness have higher mortality rates, due to early euthanasia (Devillers and Conte, 2012). Lameness is a massive burden to farms that need to minimize culling and euthanasia for optimal production.

Lameness is not a singular disease but a common clinical symptom of various ailments, both structural and functional that are observable by changes in gait (Stavrakakis et al., 2014). Because lameness can be caused by multiple factors, it can be highly difficult to treat successfully within a production setting. The leading causes of lameness have been found to be genetic or acquired musculoskeletal weakness, infections, injures, nutrition deficiencies and systematic diseases that attack the musculoskeletal system (Stavrakakis et al., 2014). Some of the issues are more difficult to prevent, such as injury and infection, yet it is possible to reduce the chance of injury and help to decrease the stress on the musculoskeletal system by correcting small issues before they lead to long term damage.

Lameness is defined as the inability to use one or more limbs in a normal fashion while generally displaying a normal degree of alertness and coordination in the unaffected limbs (Pluym et al., 2013; Abell et al., 2014). Lameness severely limits the welfare of the sows and impacts the health of the sow negatively. In the sow herd about 5-20 percent of lameness is due to foot lesions, the most common of which is the overgrowth of the claw (Pluym et al., 2013). Overgrown claws inhibit the sow from normal locomotion and behavior. This overgrowth can lead to leg weakness, which causes the sow to be unable to eat and therefore unable to nutritionally maintain production of milk. This lower production of milk lowers the weaning weight of her piglets (Pluym et al., 2013). For both the wellness of the sow and her litter, lameness negatively effects the overall welfare of the animals.

Claw Lesions

The most common claw lesions are cracks, overgrowth or tear of the different parts of the main claws or the dew claws (Nalon et al., 2013). These issues are sub-categorized by location such as side wall, white line, sole, heel, heel-sole junction (Nalon et al., 2013). Overgrowth of claws and dewclaws are two of the most common of the claw lesions (Lisgara et al., 2016). There is a need for trimming in the cases of claw and dewclaw overgrowth on the farm (Pluym et al., 2013). Functional trimming is important as a preventative measurement when combating lameness. Long dew claws can get stuck in the slots of slatted floors, putting the sow at risk of amputated claws (Pluym et al., 2013). Tearing the dewclaw is extremely painful due to exposure of the corium, which leads to lameness. Treatment of any type of lameness is frequently awkward with low rates of recovery (Pluym et al., 2013). Being neither economical nor productive, treatment is not the best route to follow for a producer. As treatment yields inconsistent results, there is merit in utilizing preventative techniques (Pluym et al., 2013). During gilt development, claw shape and size will dictate the structure of the limb due to a combination of genetics, management and nutrition (Lisgara et al., 2016). Therefore, claw conformation in gilts should be part of the section criteria for sow replacement.

With sows that are in group housing, there is a higher prevalence of claw lesions compared to individually stalled sows (Pluym et al., 2013). The increase is due to increase in movement around the pen, which increases the chance of amputation of the claw or dewclaw, along with an increase in possible aggressive interactions where on sow pushes another sow around and causes claw injury. This increase in claw lesions means that there is going to be a continued growth in lameness of sows as more farms switch to group confinement. In multiple studies, the majority of sows were found to have at least one or more claw lesions (Calderón Díaz et al., 2014; Lisgara et al., 2015). Claw lesions have been shown to be a major cause of lameness in sows (Calderón Díaz et al., 2014). The combination of lesions on the dorsal and ventral areas of the claws also negatively affected the reproduction of the sow and facilitate the invasion of bacteria in to the corium (Lisgara et al., 2015). When examined after culling, the majority of animals with severe lesions had evidence of laminitis (Lisgara et al., 2015).

Claw lesions have been shown to have a negative effect on production of sows. Heel lesions and wall cracks have been shown to decrease litter weight, increase pre-weaning piglet mortality, increased chance of stillborn and crushed piglets (Lisgara et al., 2015). A decrease in feed consumption as a result of claw lesions can be linked to the existing inflammatory process and impaired locomotion (Lisgara et al., 2015). This impaired locomotion is illustrated by the higher rate of lying and lower rate of standing in sows with claw lesions (Lisgara et al., 2015).

Sow Housing

Housing of sows is changing due to welfare concerns. While stalls have benefits, such as easy management, individual feeding and reduced aggressive encounters between individuals, there are drawbacks to individual stalls such as freedom of movement, which is severely restricted (Harris et al., 2006). Within individual stalls, sows do not have to move around to reach their feed and water. Thus, these confined sows have been shown to have reduced cardiovascular fitness, reduced muscle weight and bone strength, increased morbidity, and they engage in more unresolved aggression (Harris et al., 2006). The move towards group housing is driven by the attempt to help the overall welfare of the sow.

Lameness has been shown to be higher in group-housed sows than their individual-stalled counterparts, primarily due to aggressive interactions and increased mobility (Anil et al., 2003; Anil et al., 2009; Traulsen et al., 2016). The increase in sow interactions, along with the danger of limbs being stepped on, causes group housing to yield more injuries within the herd as compared to stall housing. There is also an increase in aggressive interactions within group housing due to competition over feed resources (Anil et al., 2003). Dominate sows will push the other sows around to acquire as much feed as possible, which can lead to injury of the other sow. This aggressive behavior in group housing is seen in all feeding methods to varying degrees, but can be decreased by feeding high fiber diets to reduce appetite, and providing environmental enrichment (Anil et al., 2003). Reducing appetite decreases the competition between the sows over feed and enrichments provide another source of entertainment besides fighting over feed.

While in stalls, sows cannot walk or turn around due to the tight space, which increases in restriction as the sow progresses through her pregnancy (Anil et al., 2003). This prevents the sow from being able to shift around as much, which can lead to pressure sores at her joints. Negatives of the stalls have led to gestation stalls being banned or phased out of some European countries (Harris et al., 2006). Recently, the United States has followed the European countries lead and phased out gestation stalls. With welfare becoming a growing issue within all industries, gestation crates are part of the past.

One of the major drawbacks to group housing is the poorer condition of grouped gilts' feet and legs (Harris et al., 2006). This decrease in limb health could transform lameness into a larger issue within a sow herd than currently seen. The poorer condition of the claws results in a higher lameness visual score (Harris et al., 2006). With larger numbers of animals with high lameness scores, the welfare of the herd as a whole is compromised. The higher lameness could be linked to pen design features and the opportunity for increased locomotion on uneven slatted floors (Harris et al., 2006). Sows have more opportunity to be injured due to increased walking and having to compete to get to feed and water (Calderón Díaz et al., 2014). Another contributing factor with grouped housing is mounting by estrus sows (Harris et al., 2006). Sows that have skeletal weakness would not be able to successfully tolerate being mounted without injury occurring.

Flooring

Concrete slatted flooring has a negative effect on the leg health, with dew claw overgrowth and wrenching, heel lesions all of which negatively effects the sows' gait pattern (Cador et al., 2014). In large-group housing systems the risk factor for leg disorders increases (Cador et al., 2014). It is suggested that feeding practices affect sow leg disorders (Cador et al., 2014). This could be a direct effect of feed not matching the needs of a gestating sow. Overall, it has been thought that extreme body conditions might be detrimental to leg health (Cador et al., 2014). Both ends of the spectrum would put the sow under more stress. When looking at gilts, the risk of culling due to lameness is higher than in sows (Cador et al., 2014). The higher nutritional requirements of the gilt due to growth may be a cause of higher lameness rates.

Another risk factor is dirty floors and high ammonia levels in activity areas (Cador et al., 2014). Dirty floors decrease the coefficient of friction of the floor, causing more slipping to occur compared to clean floors. The ammonia also reduces horn rigidity and horn elasticity (Cador et al., 2014). The weakening of the horn promotes the degradation of keratin by bacterial enzymes and may cause foot injuries (Cador et al., 2014). Bacterial penetration of the claw is responsible for painful inflammations and is facilitated on dirty floor (Cador et al., 2014). The inflammation increases the lameness score of the sow. Yet freshly cleaned floors increase slipping rates, which can lead to claw lesions (Cador et al., 2014). Wet concrete causes high slipping rates compared to dry concrete.

In the study by Calderón Díaz et al. (2014) 42 sows were housed in slatted concrete floored gestation stalls and 43 sows were housed in slatted concrete floored loose-housing with 20 solid concrete resting pads. Sows from each group were then moved into farrowing crates, 48 crates with slatted steel floors and 37 crates with cast iron. Results showed that the sows that were loose-housed during gestation had a greater risk of being lame when transferred to farrowing crates. The loose-housed sows were in dynamic groups, which lead to high levels of aggression. The higher aggression within the group lead to higher lameness compared to the gestation stall group. The slatted floors that were in the loose-housing did not provide adequate support to claws during aggressive interactions. In the study, narrow slats were used, which have been found to be associated with more lameness than wider slats (Calderón Díaz et al., 2014). Slatted concrete floors have been shown to be a major cause of claw lesion formation. The space between slats, roughness of surface and edge design all contribute to injuries (Enokida et al., 2010). All of the sows in the Calderón Díaz et al. (2014) study had deterioration of claws after they moved into farrowing crates. This is due to both the slatted steel and cast iron having large void ratios that increased pressure on the claw that is in contact with the slate (Calderón Díaz et al., 2014).

Sow Health

Lameness causes sows to be unable to attain optimal breeding efficiency due to culling before they attain their peak production (Anil et al., 2009). This causes a large turnover of breeding animals, which leads to the animal not reaching maximum financial productivity. Not only are the sows culled before they reach peak production, but they are also under extra scrutiny when shipped to market for sale (Anil et al., 2009). This means that producers are unable to make up for the money they lose when culling a younger animal.

When looking at different lameness levels based on gait abnormalities, it is relatively easy to distinguish a severely lame sow from healthy sow but is difficult to correctly distinguish a mildly lame sow from a healthy sow (Anil et al., 2009). This shows that the subjective tests have inconsistency from sow to sow. Even though it is difficult to differentiate, early detection is critical in preventing the afflicting condition from deteriorating (Anil et al., 2009). This early detection favors using gait analysis to differentiate lame and non-lame sows. Early detection allows producers to receive the full salvage value of the sow or provide her with timely and effective treatment (Abell et al., 2014). This allows for better management of the sow and a decrease in lost revenue due to a permanently lame sow. When looking at horses, it has been shown that good conformation and health status of the animal at a young age is associated with an increase in the longevity of the animal (Jönsson et al., 2014a).

The total number of pigs born alive per sow farrowed was less for lame sows than non-lame sows (Anil et al., 2009). This is a combination of fewer farrowing cycles and not reaching peak productivity before being culled. This is illustrated by a reduction in longevity, fewer live born pigs, and fewer numbers of such sows that farrowed again, along with possibly crushing piglets due to a decreased ability to make postural changes in lame sows (Anil et al., 2009; Lisgara et al., 2015). A low producing sow, that also has an increased chance of crushing the piglets, is an economically poor choice when compared to a sow that has more piglets that are not at a high risk of being crushed. The lower production can be connected back to reduced feed intake by the sow, which leads to lower weaning weights and higher mortality rates (Abell et al., 2014). These smaller and lighter litters will compound the revenue loss that is seen while trying to treat lameness in the sow.

Nutrition

Nutrition is a vital part of the production facility as it is the biggest cost and has the largest effect when producing pigs. Malnutrition leads to impaired horn production, especially when there is insufficiency of amino acids, vitamins or minerals (van Riet et al., 2016). Both feed and water intake of the sow are correlated to the weaning weight of the piglets (Kruse et al., 2011). The intake of both feed and water have been shown to be negatively impacted by lameness, and therefore the weight of the weaned piglets are negatively impacted as well. Claw makeup is based on nutrients that include fatty acids, the amino acids cysteine and methionine, the minerals calcium, zinc, copper, selenium, manganese and chromium and vitamin A, D, E and biotin (Pluym et al., 2013). These nutrients are provided to the sow through her diet, yet may be in deficit during lactation when the sow's nutrient needs are extremely high. Dietary needs should be carefully assessed during the different stages of production to assure that the diet meets the pig's nutrient profile.

Microminerals

When looking at nutrition, it is important to consider the microminerals within the diet. Microminerals have an important role in maintaining claw quality (Lisgara et al., 2016). Trace mineral intake and storage is a vital issue to consider because these minerals are required for metabolic function, such as immune response, antioxidant properties, energy metabolism, and other physiological functions (Liu et al., 2016; Lopes et al., 2017). Microminerals, such as zinc and manganese, are important because they are needed for vital biochemical mechanisms needed for animal growth and development (Lopes et al., 2017). Organic minerals are absorbed by intestinal carriers of amino-acids and peptides, unlike inorganic minerals that is transported by intestinal transporters, which prevents minerals from competing for absorption through the same mechanisms (Lopes et al., 2017). The change in absorption improves not only bioavailability, but also improves movement of minerals to tissues and retention within those tissues (Liu et al., 2014; Liu et al., 2016; Lopes et al., 2017). However, organic minerals are traditionally more expensive when compared to inorganic minerals, even when the larger inclusion rate of inorganic minerals in the diet are taken into consideration (Lopes et al., 2017). It has also been shown that pigs that received the same level of organic minerals as the pigs that received inorganic minerals had lower levels of zinc, manganese, and copper in the fecal material, showing that the minerals were retained at a higher level (Creech et al., 2004; Lebel et al., 2014; Liu et al., 2014; Liu et al., 2016). Decreasing the copper and zinc in manure allows for more manure to be able to be spread without causing toxicity within the plants (Creech et al., 2004). Zinc- dependent metalloenzymes, which support keratinization of keratin proteins, and copper, which provides the enzyme activity for keratinocyte differentiation are required for horn growth (Basurto et al., 2008; van Riet et al., 2013). Without keratin, the claw wall would become weak and more susceptible to claw lesions.

Cu is connected to osteoblast activity and bone deposition on the calcified cartilage matrix (van Riet et al., 2013). Cu has also been shown to be required for connective tissue development due activating an enzyme that is essential to collagen cross-linkage (van Riet et al., 2013). Manganese is essential for horn production due to its activation of pyruvate carboxylase (van Riet et al., 2013). Manganese is required for mucopolysacccharide synthesis, which is a component of cartilage (Lopes et al., 2017). A manganese deficiency would result in the repression of the immune and central nervous system (Lopes et al., 2017). For all minerals, requirements have been set by using breakpoint analysis within a dose-response study, in which the mineral is increased in steps until the requirement is met (Barrey et al., 2012). Some minerals, such as Zn and Cu, are fed at pharmacological levels, which provide positive effects that go beyond the requirements, such as increased growth rate and improved gut health (Barrey et al., 2012; Dębski, 2016). Feeding high levels of heavy metals such as Zn and Cu is a concern due to the pig excreting it and causing adverse effects on the environment (Hernández et al., 2008).

Organic mineral complexes have been shown to increase mineral absorption and retention in pigs (Hernández et al., 2008; Lisgara et al., 2016). When feeding an organic complex for Zn and Cu, with its higher bioavailability, there is an increase the improvement of pig performance, even when fed at lower levels (Hernández et al., 2008; Dębski, 2016). The higher absorption and retention is important as mineral requirements may be higher than current recommendations (Hernández et al., 2008). Concentrations of Zn have been shown to increase within the liver and heart when provided by an organic source compared to an inorganic source (Liu et al., 2016). In Liu et al (2016), organic trace minerals were shown to increase the activity of Cu/Zn-Sod, ALP and GSH-Px enzyme compared to the inorganic minerals.

Immune Response

Lameness causes a release in cytokines due to inflammatory processes, which can induce anorexia and lethargy (Anil et al., 2009; Lisgara et al., 2015). Sows will be less social as well as less likely to maintain hydration and body condition. These effects, plus the decreased desire to move due to pain and discomfort, causes a marked decrease in feed intake and movement (Anil et al., 2009). With a drop in body condition, the sow will have less reserves to provide milk for her piglets and will not be as breeding sound as a well-conditioned animal. Sows that ate less than 3.5 kilograms of feed per day during the first two weeks of lactation were more likely to be removed from the herd before their next parturition (Anil et al., 2009). This means that sows that are unwilling to eat enough to maintain healthy body weight will not be retained in the herd.

It has been found that lateral claws are larger than medial claws (Pluym et al., 2013). The difference between claws is more pronounced on rear feet than on front and increases as pigs age (Pluym et al., 2013). As the pig ages, the small differences between the two claws will expand. As the difference increases, the frequency of claw lesions increases (Pluym et al., 2013). The unevenness of the two claws will cause the lateral claw to carry all of the weight of the limb, while the medial claw will grow without contact with the floor. The discrepancy has been associated with a higher culling risk (Pluym et al., 2013). The difference in the claw size has been shown to be hereditary to a certain extent. This means that selection of replacement gilts with evenly -sized toes may help to control the development of claw lesions (Pluym et al., 2013). Evenly-sized claws help to keep the pressure constant across the claw to decrease lameness and lesions from occurring. The problem of uneven claws is exacerbated by the natural swivel gait in the rear limbs which displaces more weight onto the outside claws (Van Amstel, 2011). This causes claws that were already carrying the majority of the weight to have more force placed on them, allowing the uneven distribution to be magnified.

Claw Trimming

Claw trimming is routine in other production animal industries, such as the equine, ovine and bovine, yet is not common in the swine industry. Older studies suggest routine claw trimming in pigs is necessary, however more recent studies do not recommend claw trimming as a prophylactic measure in group- housed sows (Pluym et al., 2013; Lisgara et al., 2016). This discrepancy leads to an industry that largely does not trim claws as a preventative measure. In one study it was found that preventative claw trimming did not show improved longevity or a clear effect on claw lesion development, therefore not supporting the additional labor and costs associated with regular, preventive claw trimming (Pluym et al., 2013). Even though some studies have deemed claw trimming as unproductive, most professionals suggest that trimming is needed for the health and welfare of the sows.

Trimming is strongly recommended when the claws of the sow are overgrown as a corrective treatment (Lisgara et al., 2016). One of the latest study did show that claw trimming had a positive effect on gait in long clawed sows (Tinkle et al., 2017).Trimming includes using hoof nippers and grinders to shorten and reshape the claws. The overgrowth of the claw is trimmed using hoof nippers to decrease the length of the claw to 45-55 millimeters (Van Amstel, 2011; Tinkle et al., 2017). Cutting the length of the claw first with nippers shortens the time that is needed to shape the hoof with the grinder. Then the grinder is used to reshape the walls of the hoof to take out the curving that occurs with overgrowth of claws (Van Amstel, 2011; Tinkle et al., 2017). Straightening the wall helps to maintain the correct pattern of growth for longer after trimming. Dew claws can also be trimmed back to prevent trauma and interference during normal locomotion (Van Amstel, 2011). Trimming dew claws helps to decrease the risk of lameness due to injury. Foot baths have also been recommended, with or instead of trimming. It has been suggested to use copper sulfate, zinc sulfate and formalin (Pluym et al., 2013). The mixture within the foot bath would decrease bacterial populations, which decreases chance of infection. Environmental concerns over copper and zinc sulfate cause them to be ill-advised to use, and formalin is a known carcinogen (Pluym et al., 2013). Therefore, while this mixture is useful on the farm, it should be carefully used by diligent workers.

Lameness problems can be corrected for by trimming claws when problems are noted (Van Amstel, 2011). Early detection is essential for correction to help the sow overcome her lameness. Structures such as the corium, basement membrane and germinal layers of epidermis are critical for horn formation and growth of claw (Van Amstel, 2011). Learning how to maintain the health of these structures is extremely beneficial for prevention of lameness. When claw lesions involve the corium, they cause pain and lameness (Van Amstel, 2011). These two reactions cause the welfare of the sow to be compromised, creating the need for producers to prevent these claw lesions from occurring. The most likely causes of corium becoming compromised are inflammation due to trauma, infection or inappropriate nutrition (Van Amstel, 2011). These issues all lead to the claw becoming unable to function naturally due to structural integrity degeneration.

When blood flow to the corium is compromised, horn growth is affected which causes horizontal or vertical wall cracks, erosions and ulcers in the sole or heel of the animal (Van Amstel, 2011). Each of the defects of the claw causes negative effects on the sow's walk, therefore causing her to be less likely to behave as she naturally without the defects.

Subjective Analysis

Lameness can be assessed using subjective methods, such as gait and locomotion scoring (Stavrakakis et al., 2014). These methods are useful on farms for looking at the herd on a daily basis, but are dependent on the scorer being knowledgeable and proficient with the scoring system. Scoring systems are successful in allowing the observer to quickly and affordably quantify lameness prevalence in the herd on any particular day (Abell et al., 2014). This helps the producer to regularly check the herd for lameness issues without having to bring an expert into the farm.

One of the major problems with lameness scoring systems is that there can be disagreement between lameness scores that are given to a sow (Abell et al., 2014). These discrepancies between scorers can be attributed to viewing the sow day after day. This leads to inter- or intra-scorer variation, where the same sow is given two different scores by the same or two different scorers (Abell et al., 2014). Giving two different scores to the same sow means that her lameness is downgraded in one of the scores, which allows a lame sow to stay in the herd.

Visual scoring requires substantial training to make users both accurate and proficient when evaluating sows for lameness (Abell et al., 2014). The training time needed to create a skilled worker for evaluating lameness makes the process an expensive for the producer to have to validate. The long time frame that it takes to produce skilled evaluators, along with high employee turnover rates, makes this practice inefficient to train for lameness detection (Abell et al., 2014). While the scoring system is relatively cheap and is used at most farms, there is a commitment that must be made to maintain a trained evaluator on the farm. By having objective measurements, the discrepancies between scorers will be eliminated and uniform method to detect sow lameness will be established (Abell et al., 2014). This would provide a sensitive and definitive detection for lameness.

Gait Analysis

Gait analysis is a widely accepted useful tool that is more accurate in assessing gait deviation that visual gait assessment (Wren et al., 2011). With the evolution of higher definition cameras that capture higher frames per second, experiments can now be run by looking at motion in a frame by frame process (Tinkle et al., 2017). Looking at the different measurements of time and motion, patterns occur that distinguish lame and sound sows from each other (Mohling et al., 2014). The systems that are used allow for less user error due to less control going to the user to define measurements. Using gait analysis verses subjective methods of classification is more successful in targeting longevity characteristics and preventing lameness (Stavrakakis et al., 2014). Isolating for these characteristics increases welfare and improves economic output. The increase that is seen, in conjunction with sows that are in the herd for longer, makes each sow a higher producer. Yet the biomechanical study of sows is a complex process that require simplification before it will be usable on farms (Stavrakakis et al., 2014). Simplifying the system may take years as technology will have to catch up to the demand. The gait analysis system is expensive and labor intensive, with risk of damage or loss of equipment while collecting data (Abdul Jabbar et al., 2017). These drawback plus the technical details that are required when setting up the systems would not make it useful on a farm.

Even with a subjective method that works, it is important to develop a system that uses quantitative methods to identify gait parameters that are more sensitive than what is visible to the observer (Stavrakakis et al., 2014). Lameness is a progressive problem that can cause long term damage to the musculoskeletal system before visible signs appear. It has been shown that using gait analysis parameters detect pigs with abnormalities which are not observed by visual observation (Stavrakakis et al., 2014). This illustrates that the system is more sensitive and can be used to detect issues before they visibly impair the pig. An increased sensitivity system has the potential to complement or even replace existing subjective selection of breeding animals (Stavrakakis et al., 2014). The ability to select for decreased lameness in the breeding herd would have the potential to decrease turnover rates and increase production in the long term. The increase in production would be due to an increase in longevity, an important quality when selecting future breeding stock (Stavrakakis et al., 2014) which leads to sows reaching their full breeding potential. Focusing on musculoskeletal conformation, mobility and freedom of disease is essential for increasing longevity in sows (Stavrakakis et al., 2014). By increasing the musculoskeletal correctness and health, longevity will be greatly increased compared to current animal's predicted lifespan.

Biomechanics

When studying lameness, or even how an animal moves naturally, there needs to be set measurements between animals to help differentiate problems from the normal gait pattern. Biomechanics is the study of the mechanical nature of biological processes. In the case of this experiment, it is the study of how the animal's locomotion is occurring and what is disrupting the natural movement. Walking is a four-beat gait with alternating two- and three-limb support phases (Thorup et al., 2007). The pattern holds true for the majority of quadrupeds due to their step patterns. Sound sows will have a steady pattern of the two and three limb support phases during their walking stride duration. Sows carry 54% of their weight on their forelimbs (Thorup et al., 2007). The distribution of weight is seen in quadrupeds because their center of mass is located around their shoulder area. The higher load and impacts on the forelimbs due to weight distribution causes leg problems at a higher frequency in fore rather than rear legs (Thorup et al., 2007). This difference in weight distribution also leads to differences in gait biomechanics when comparing the rear legs to the front.

In lame sows, there is a tendency of shorter stride lengths, lower velocity, and longer stance times than sound sows (Abell et al., 2014). While the differences may not be clear to the eye, they are detected by the cameras and can be analyzed in a kinematic software program to give producers distinctions between lame and non-lame sows. Variations in stride pattern, due to pain, are present in sows with poor limb structure more often than in sows with desirable limb structure (Abell et al., 2014). Having measurements that can be used to compare limbs during movement can help to prevent issues with the sows before long term issues arise.

Gait analysis has been shown to be an objective tool compared to traditional systems of lameness scoring, which are highly subjective with varying degrees of inter- and intra-observer correlation (Mohling et al., 2014). This allows measurements to be more consistent with gait analysis, therefore caretakers have a reliable method in which to judge the lameness level of the sow in which the user error is decreased. It has been shown that gait analysis programs are good tools that exhibit differences in gait characteristics between sound and most lame sows (Mohling et al., 2014). The ability for more sensitive measurements to differentiate levels of lameness that are undetectable to the naked eye makes quantitative gait analysis a promising tool for diagnosis of early lameness symptoms. Yet the systems are hardly applicable on farm, being costly and time consuming to do the analysis in the program (Devillers and Conte, 2012). While the systems are expensive, they have the potential to save the producer money.

Predictive Measurements

Gait analysis can be a predictive measurement for how adults will move based on their gait as a young animal. The duration of swing in four month old foals has been shown to be similar to that of an adult horse, showing that swing is a good indicator of gait quality (Back et al., 1995). In the same study the stance and stride duration increased as the limbs increased in length (Back et al., 1995). The increased amount of time for stance and stride duration came from the increased protraction and retraction of the limbs (Back et al., 1995).

Gender has been shown to have an effect on gait quality and behavior. In Warmblood foals, it has been shown that females have a higher percentage of premium status scores (Bhatnagar et al., 2011). This score in combination with the females higher score for type and conformation, overall development as related to age and total score (Bhatnagar et al., 2011) shows that there is difference in gender for conformation, development and quality of movement.

Selection

To have a high production herd, selecting high quality gilts is important since production of individual sows impacts the overall productivity of the herd (Roongsitthichai et al., 2013). Genetically, the correlations for conformation and longevity in horses were 0.13 to 0.3, and the correlation for good health and longevity was 0.3 (Jönsson et al., 2014a). In swine, leg weakness and lameness has been linked genetically (Anil et al., 2005), but genetics are only a small part to solving the problem of lameness. Heritability of conformation in pigs has been shown to be low to medium with heritability estimates for conformation traits exact values varying within the literature from 0.01 to 0.37 (Aasmundstad et al., 2014; Le et al., 2015; Le et al., 2017). Some of the factors that might be causing the variability are testing scheme, scale for scoring and the subjectivity of evaluators, along with age of pigs and view that is being scored(Le et al., 2015). There has been shown a positive correlation between good limbs and production in sows (Le et al., 2015; Le et al., 2017). Using gait analysis to provide precise measurements of conformation and morphology would improve heritability, as conformation characteristics possess higher heritability when objective over subjective methods are used (Aasmundstad et al., 2014).

In pigs, it has been shown that claw and dewclaw lengths are influenced by genetics and age (Lisgara et al., 2016). When looking at heritability, there is a wide range of values of 0.01 to 0.61 that are dependent on breed and statistical method for claw size asymmetry (Pluym et al., 2013). Abnormal hoof growth has moderately heritable between 0.24-0.38, which is associated with increased culling in sows (Pluym et al., 2013). Mineral supplementation can decrease the overgrowth of claws, which shows that genetics are not the only factor, but dewclaws are not affected (Lisgara et al., 2016). The lack of change in dewclaw length illustrates that genetics is the majority contributor to dewclaw overgrowth.

Gender and Genetic Effect on Behavior

Differences in behavior between the two genders has been documented across many species(Berenbaum et al., 2011). All types of behavior have been shown in humans to be influenced by genes, physiology and by the brain (Berenbaum et al., 2011. In cattle these differences in behavior are thought to be a reflection of temperament (Broucek et al., 2013a; Broucek et al., 2013b). In all species of animals, hormones cause permanent changes in behavior that dictate the differences in the genders (Berenbaum et al., 2011). These changes cause behavior to differ between females, intact males and castrated males. In four-month old Warmblood foals, gender impacts the daily activities and interactions to reflect behaviors that will be seen later in life (Kurvers et al., 2006). The difference in behavior between the two genders may explain why training has a different effect on the two genders. In cattle, females have been categorized as excitable or difficult to handle, with higher temperament scores than steers (Broucek et al., 2013b). This means when working with heifers, handlers had to be calmer and slower with their approach compared to steers. Yet, in Broucek et al, (2013b) heifers spent more time with new people compared to bulls. This is thought to be due to intact males being leerier of people than the females. This leeriness can be seen in horses as well with handlers categorizing yearling females as more skittish, suspicious and excitable compared to their males counterparts (Duberstein and Gilkeson, 2010). In pigs, castrated males have been thought to be victims of tail biting more often due to being more docile with age compared to females (Schrøder-Petersen et al., 2010). The females are thought to bite more often because they are generally more engaged in exploration and social behaviors (Schrøder-Petersen et al., 2010).

Part of temperament also can be a factor of genetics. Sire lineage has been shown to influence behavior of offspring in cattle (Broucek et al., 2013a). Some studies have indicated that cattle locomotor behavior is effected by genotypes (Broucek et al., 2013a; Broucek et al., 2013b). It has been illustrated that there are differences between sire lines in capability to learn (Broucek et al., 2013a). Sire lines in cattle were also shown to have significant behavior differences within an open-field test (Broucek et al., 2013b). Genotype has a significant effect on vocalization patterns, illustrating the variance in tameness due to genetics (Broucek et al., 2013b).

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CHAPTER 3

THE EFFECTS OF TRAINING ON KINEMATICS IN A MIXED GROUP OF GROWER PIGS OVER A WEEK

Introduction

Gait analysis is a useful technology that is being used to study lameness. Gait analysis is defined as the dynamic observation, record and analysis of the structure and function of the foot, lower limb and body during walking. Gait analysis is a widely accepted useful tool that is more accurate in assessing gait deviation than visual gait assessment (Wren et al., 2011). In horses and dogs, gait analysis has been used for years to improve welfare. In pigs, gait analysis is a relatively new tool. Using gait analysis versus subjective methods of classification is more successful in targeting longevity characteristics and preventing lameness (Stavrakakis et al., 2014). By isolating for these characteristics, it is possible to increase welfare and improves economic output.

Gait analysis has been shown to be an objective tool compared to traditional systems of lameness scoring, which are highly subjective with varying degrees of inter- and intra-observer correlation (Mohling et al., 2014). The systems that are used allow for less user error due to decreased user control in defining measurements. In dogs, gait analysis has been shown to explain variations in gait (Fanchon and Grandjean, 2009). Applying technology created for other animals can have issues, the biggest of which is that both horses and dogs are normally trained to walk or run while restrained. This allows for more control over speed and gait than with pigs and other livestock. In pigs, gait analysis is a new tool that needs further studying due to pigs not being lead down the track like horses or dogs. When looking at Schnabl-Feichter et al. (2017), cats were trained to walk across a pressure mat with reliable results over the first three days on the track. Like cats, there is no direct control with pigs, making training possibly more important in pigs compared to other species.

To overcome the issue of controllability, multiple studies have used chutes to guide the pigs down the track. Pigs have to be trained to go down the mat at a constant rate. The question this poses is how much training is necessary to obtain consistent results. When examining the effects of training in other species, such as horses and dogs, most animals are habituated within a day of training, but more training will help to decrease variability within the data (Fanchon and Grandjean, 2009). Trainability in pigs is an important factor to consider when using new technology, such as pressure mats. It is important to allow pigs enough time to become acquainted to the equipment for accurate results. A week was chosen based on previous methods that have been used for studies (Tinkle et al., 2017). The object of this study was to determine how many days of training in a week would produce the best results in gait analysis collection.

Materials and Methods

Experimental protocols were approved by the University of Georgia (Athens, Ga) Institutional Animal Care and Use Committee (AUP#A2017 01-018-R1). Thirty-three Choice Genetics pigs, which consisted of 17 CG 32 by EB 5 crosses (9 females, 8 males) and 16 CG 32 by EB X crosses (8 females and 8 males), were obtained at a weight of 68

+/- 5 kg from the University of Georgia Swine Unit. Pigs were brought into University of Georgia Large Animal Research Unit and given three days to adjust to their new surroundings before the study began. EB X sired pigs are bred for rapid growth, while the EB 5 sired pigs bred for meat quality (Gentics, 2014). None of the pigs used were visually lame at the beginning of the study. During the study, two pigs were removed before analysis due to visible lameness, one male from each of the sire lines. Prior to the study none of the pigs had been familiarized to the gait mat. Training occurred in conjunction with recording, so that D1 of recording would also be the first day that the pigs were exposed to the mat. Pigs were trained on the mat on D1-D5 (Monday-Friday) and again on D8 (Monday). Pigs were recorded on D1, D2, D4 and D8 while simultaneously being trained. Pigs were encouraged to cross the mat using boards and sorting paddles, which would typically be used on a farm. No treats or rewards were used during the length of the study. For this study, we used the minimum amount of stimulus to have pigs to successfully cross the track. First, paddles were used as shakers behind the pig to send them forward. Then paddles were tapped against the fencing near the pig's hindquarters. When noise did not have an effect, then pigs were tapped on their rump in an increasing rate until they moved forwards. If pigs did not respond or fought against the stimulus, they were given a minute to rest before the stimulus was reinstated along with a board, which was added to funnel their movement forward towards the mat. For every repetition across the mat, the process was repeated so that the minimum stimulus was used and that pigs would have the least amount of interference possible.

Pigs were walked back and forth through a dog bone track made of commercial hog panels across a 7.5 m GAITRite pressure mat (GAITRite, Franklin, New Jersey). Pigs were brought into the gait room from their pens one at a time. At each time point, the pigs were moved across the pressure mat in a diagonal pair footfall until 6 usable repetitions were obtained or a maximum of twenty minutes had passed from the start of the session. Each run was recorded and processed at a later time. After data were collected, pigs were returned to their pens in the Large Animal Research Unit, where they had access to ad libitum feed and water. At the end of the study, pigs were returned to the University of Georgia Swine Farm.

Recorded Analysis

Recordings from the mat were collected in the GAIT4Dog software program (GAITRite, Franklin, New Jersey). This program provides a digital copy of the pig's footfalls as they land on the mat. The footfalls are then processed so that each one is numbered in the order they land. Once all feet are assigned a number, the program designates the foot that the footfall belongs to depending on direction of travel and pattern of movement so that each foot is categorized as right front, left front, right rear or left rear. Any erroneous assignments of number or foot assignment can be corrected by the user before the run is analyzed for gait parameters. Velocity, stance, swing, stride duration, stride length, and percent stance of stride duration were measured for each video and was recorded for gait parameters. Measurements were statistically compared across the time points. For training total amount of time on the mat, time until first usable repetition, and total number of runs were also recorded and analyzed.

Statistics

Data were analyzed in SAS (version 9.4; SAS Institute Inc., Cary, NC, USA) using a PROC MIXED procedure to evaluate the differences of the front and rear limbs at the four time points as a repeated measures model. All variables mentioned above were compared at each time point. Statistical significance was considered at $P < 0.05$ for all parameters measured, and PDIFF was used to separate means where necessary.

Results

Looking across the training days for all pigs, there was a significant decrease from D1 to D4 for the total time on the mat ($P < 0.02$; Table 3.1, Figure 3.1) and time to first usable run ($P < 0.05$; Table 3.1, Figure 3.2). There was improvement crossing the mat seen across the days, which can be seen in total time and time until first usable run from D1 to D4. This also illustrates the regression that occurs across the two-day break from training. Like cats, pigs naturally will not move down the mat in a straight line every time, nor will they maintain their pace across the mat for every repetition (Schnabl-Feichter et al., 2017). While there was improvement across the week, as seen on D8 pigs fall back to their natural uneven movements and to being more uneven in their movements across the track, which makes data collection take longer amount of time.

There was an increase in velocity from day D1 to D2, D4 and D8 ($P < 0.04$; Table 3.1, Figure 3.3), with decrease from D4 to D8 ($P < 0.02$; Table 3.1, Figure 3.3). There were no significant differences for stride length across the days (Table 3.1, Figure 3.4). Stride duration decreased from D1 to D8 ($P < 0.007$; Table 3.1, Figure 3.5) and from D2 to D4 ($P < 0.04$; Table 3.1, Figure 3.5). There was an increase in stride duration from D4 to D8 ($P < 0.009$; Table 3.1, Figure 3.5). Pigs appear to move out more freely from D1 to D4 which is seen in the increase in velocity and the numerical value for stride length. There was a decrease in swing time from D1 to D2, D4 and D8 ($P < 0.02$; Table 3.1, Figure 3.6), from D2 to D4 ($P < 0.01$; Table 3.1, Figure 3.6) on all limbs, and from D2 to D8 ($P < 0.001$; Table 3.1, Figure 3.6) on the front limbs. There was an increase in swing time in the rear from D4 to D8 ($P < 0.03$; Table 3.1, Figure 3.6). There was a decrease in stance time from D1 to D2, D4 and D8 ($P < 0.01$; Table 3.1, Figure 3.7). There was an increase in stance time from D4 to D8 ($P < 0.01$; Table 3.1, Figure 3.7). A decrease was seen in percent stance from D1 to D2 and D4 ($P < 0.006$; Table 3.1, Figure 3.8) for all limbs. The decrease in stride duration, swing and stance shows that the pigs cross the mat more efficiently on D4 than on D1. On D8 velocity decreased while stride duration increased, showing that there was a regression towards the D1 values after the two-day break from training. There was an increase in percent stance for rear limbs from D1 to D8 ($P < 0.02$; Table 3.1, Figure 3.8), in the front limbs from D2 to D8 ($P< 0.0001$; Table 3.1, Figure 3.8), and all limbs from D4 to D8 ($P < 0.007$; Table 3.1, Figure 3.8).

Conclusion

This study shows that it training was not successful for pigs over a week. When looking at training, there are benefits to exposing pigs to the track, as some of the groups did have changes, but overall training will not change the gait or behavior of the pig for the long term. While improvements were made, the data across the days had not reached a plateau, which means that the pigs could need more training to provide data that is consistent across the days. Within the days, there was very little variation in gait, which shows that pigs provide consistent data during the day, but are inconsistent between the days. The inconsistency shows that more training is needed, but with the regression over the weekend, training may not provide results that last over breaks. Therefore, training, or at least exposure to the mat, is useful before collecting gait analysis but will not necessary provide consistent data.

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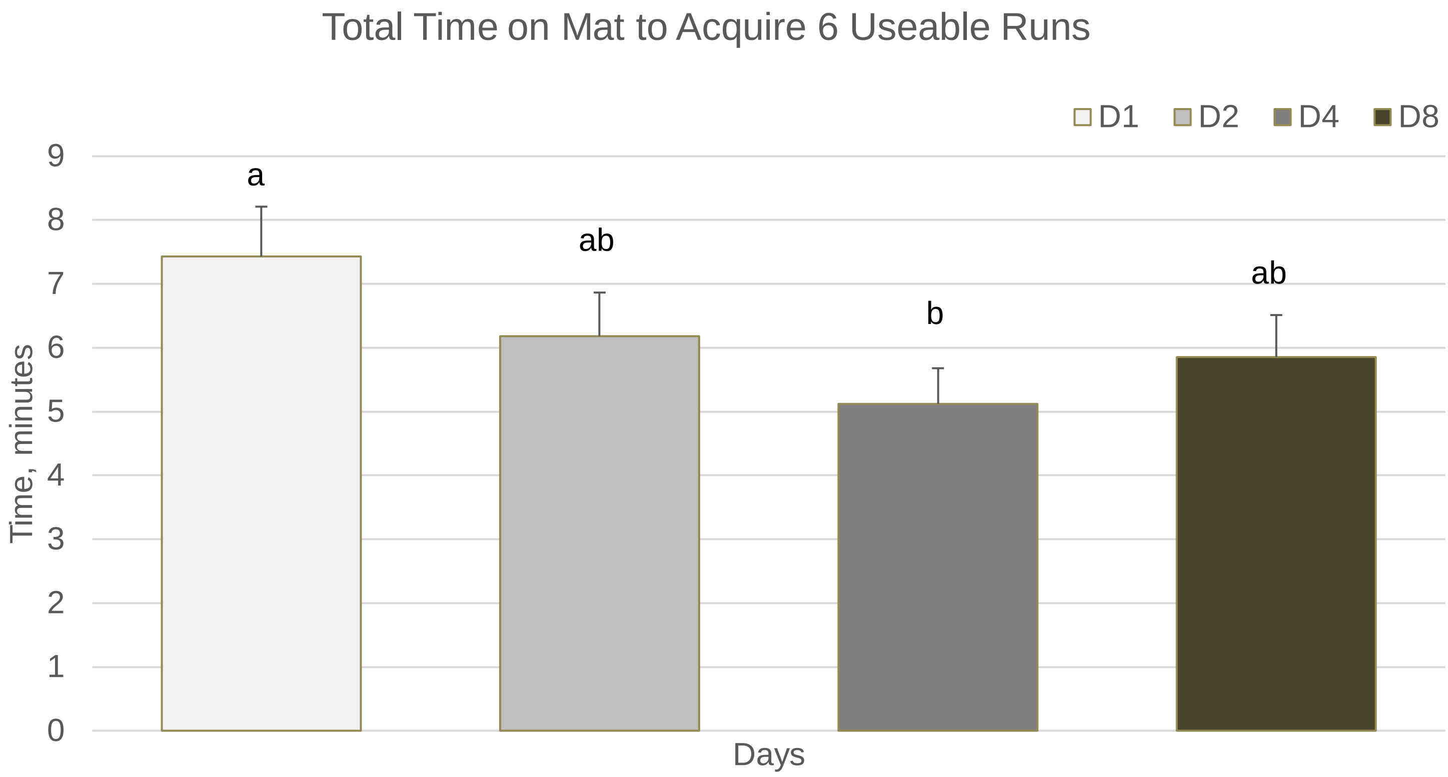
Table 3.1-Average value for days

Measurements	D1	D2	D4	D8
Total Time on mat (min)	7.43 ±0.78^{a}	6.18 ±0.68^{ab}	5.12 ±0.56^{b}	5.85 ±0.66^{ab}
Time to First Usable Run (min)	2.20 ±0.44^{a}	1.65 ±0.27 ^{ab}	1.18 ±0.24^{b}	1.73 ±0.38^{ab}
Total Runs	16.48 ±0.93	17.03 ±1.05	15.59 ±1.10	17.18 ±1.13
Velocity (cm/s)	180.30 ±3.35^{c}	194.41 ±3.09^{ab}	196.81 ±2.45^{a}	188.67 ±2.37^{b}
Stride Length Front (cm)	83.49 ±0.59	84.77 ±0.52	84.59 ±0.53	84.24 ±0.46
Stride Length Rear (cm)	83.28 ±0.59	84.57 ±0.52	84.36 ±0.53	84.01 ±0.45
Cycle Time Front (s)	0.49 ±0.008^{a}	0.46 ±0.008^{b}	0.44 ±0.005^{c}	0.46 ±0.005^{b}
Cycle Time Rear (s)	0.49 ±0.008^{a}	0.46 ±0.008^{b}	0.44 ±0.005^{c}	0.46 ±0.005^{b}
Swing Time Front (s)	0.23 ±0.002^{a}	0.23 ±0.002^{b}	0.22 ±0.001^{c}	0.22 ±0.001^{c}
Swing Time Rear (s)	0.26 ±0.002^{a}	0.25 ±0.002^{b}	0.25 ±0.001^{c}	0.25 ±0.001^{b}
Stance Time Front (s)	0.26 ±0.007^{a}	0.23 ±0.007^{bc}	0.22 ±0.004^{c}	0.24 ±0.004^{b}
Stance Time Rear (s)	0.23 ±0.007^{a}	0.20 ±0.006^{bc}	0.19 ±0.004^{c}	0.21 ±0.004^{b}
Percent Stance Front (%)	50.92 ±0.45^{a}	49.14 ±0.43^{b}	49.38 ±0.33^{b}	51.19 ±0.32^{a}
Percent Stance Rear (%)	45.69 ±0.47^{a}	43.39 ±0.43^{bc}	43.11 ±0.34^{c}	44.38 ±0.33^{b}

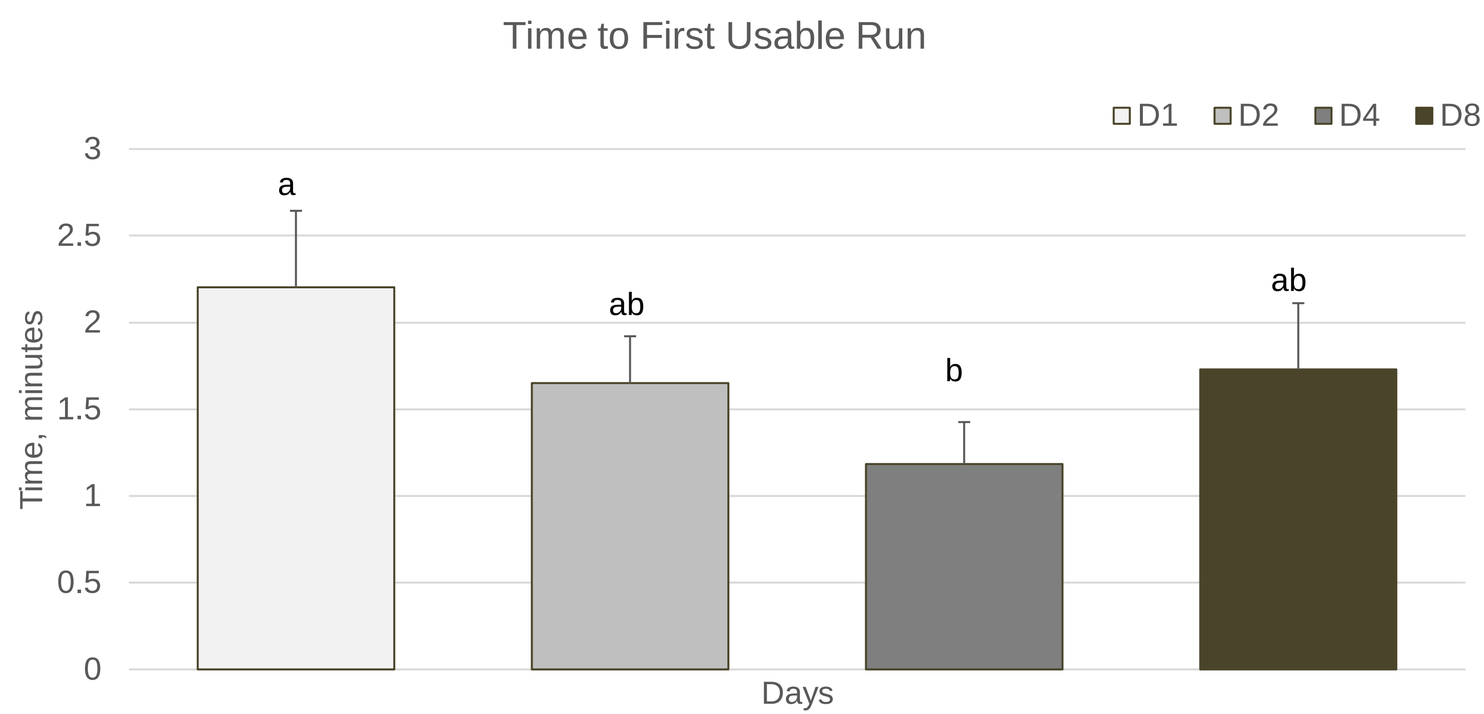
Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Figure 3.1- Average total time on mat to acquire 6 useable runs



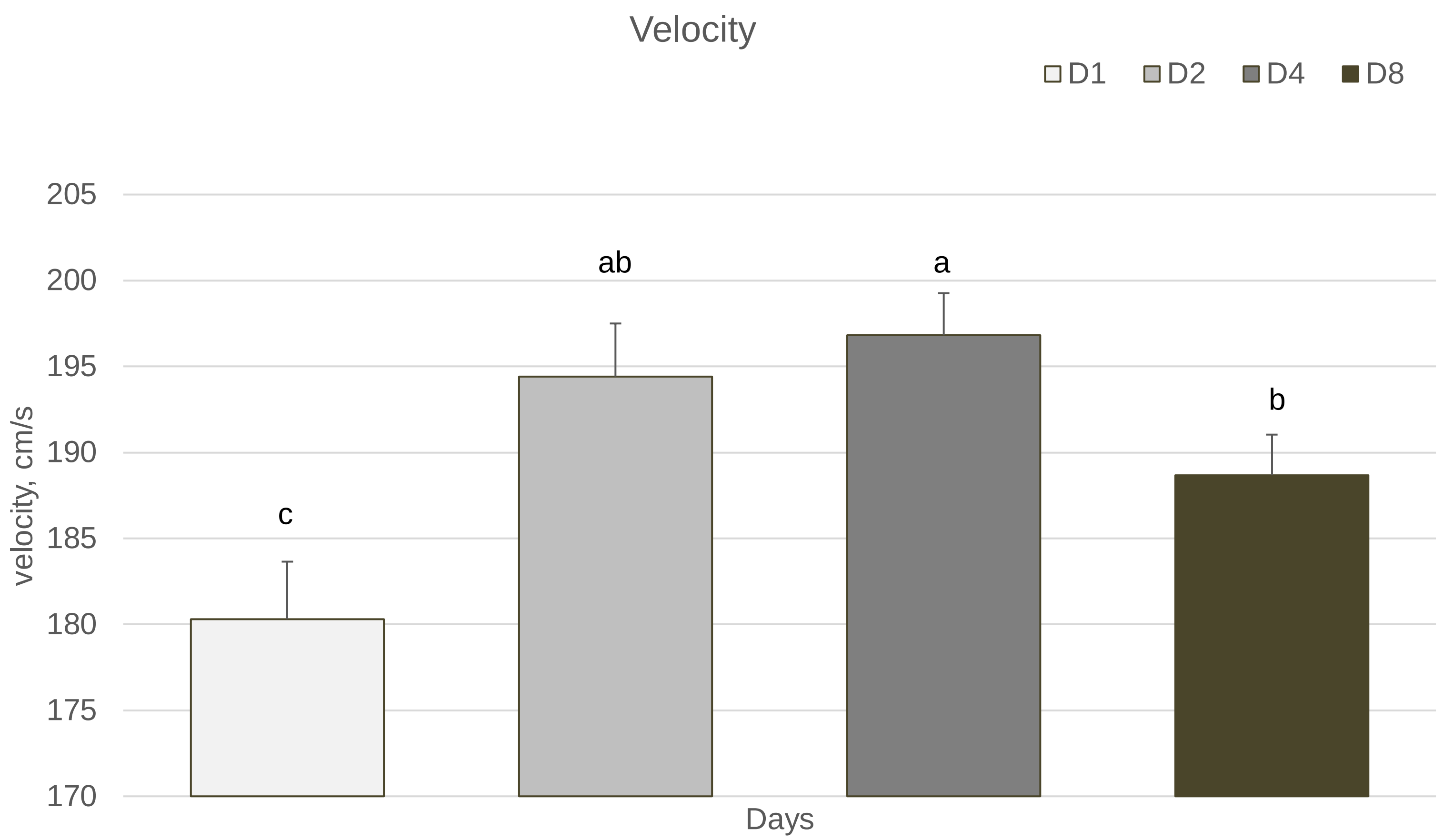
The letters signify $P < 0.05$ between the average means of the days.

Figure 3.2- Time to first usable run



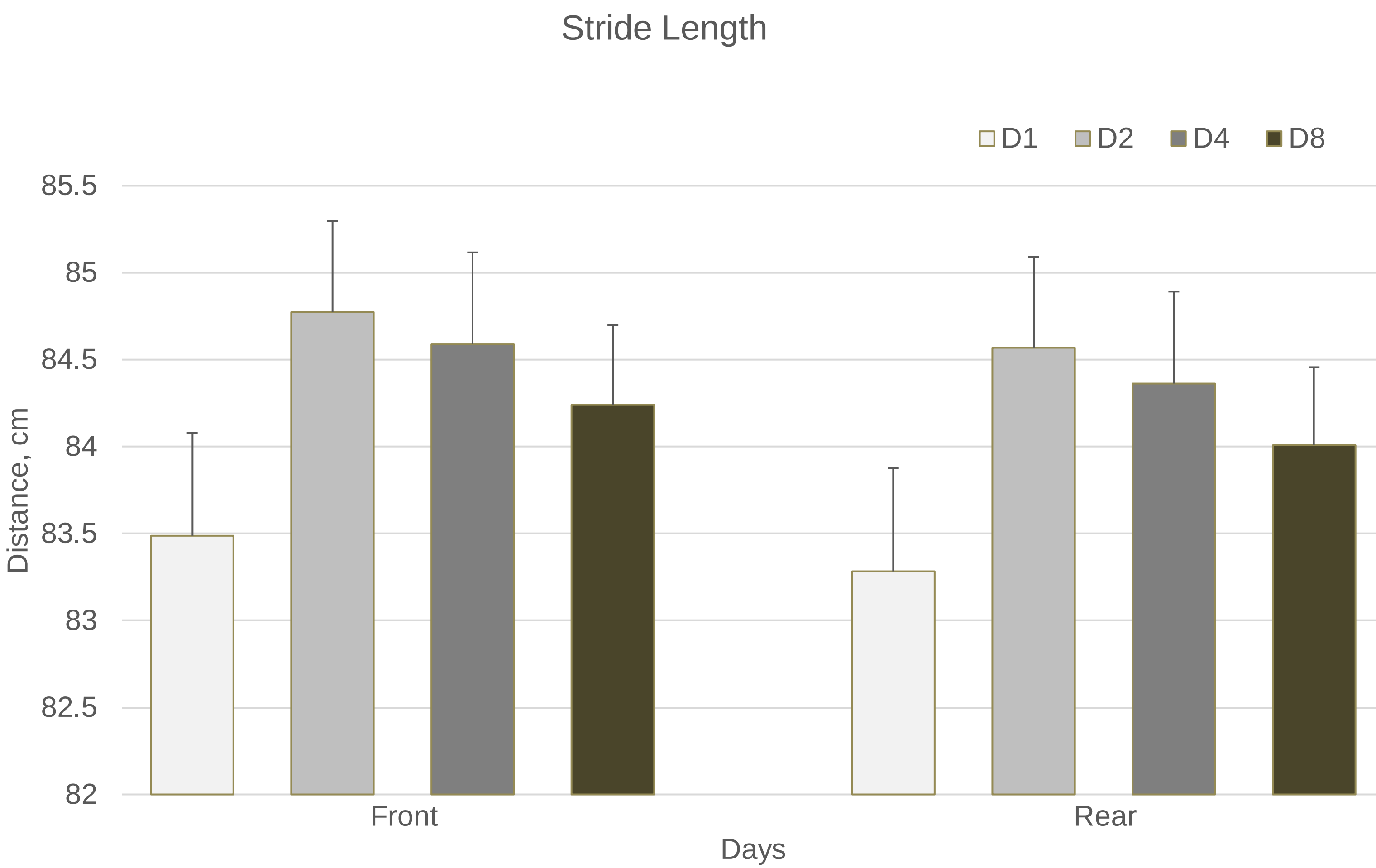
The letters signify P < 0.05 between the average means of the days.

Figure 3.3- Average velocity



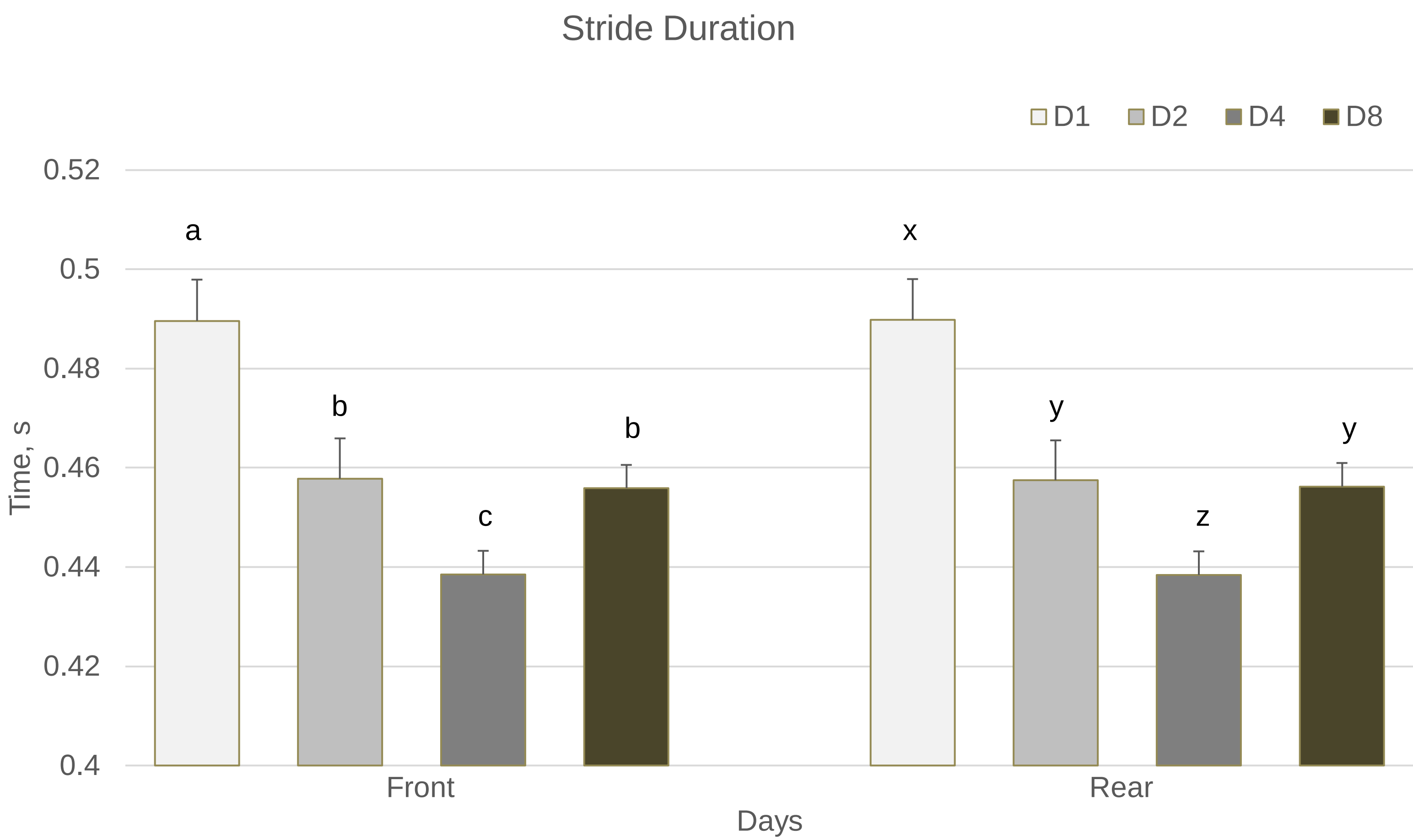
The letters signify $P < 0.05$ between the average means of the days.

Figure 3.4- Average stride length



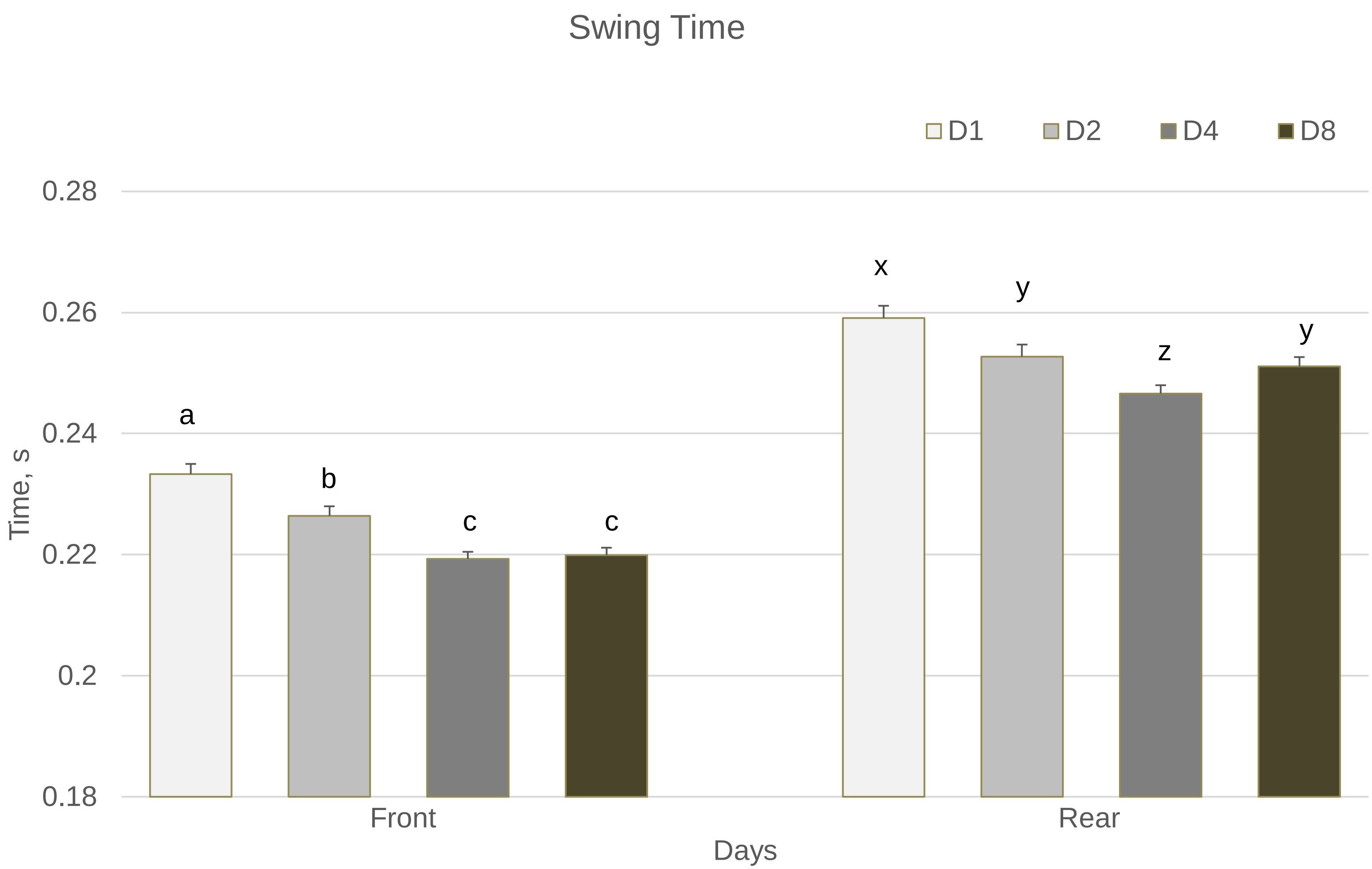
The letters signify P < 0.05 between the average means of the days.

Figure 3.5- Average stride duration



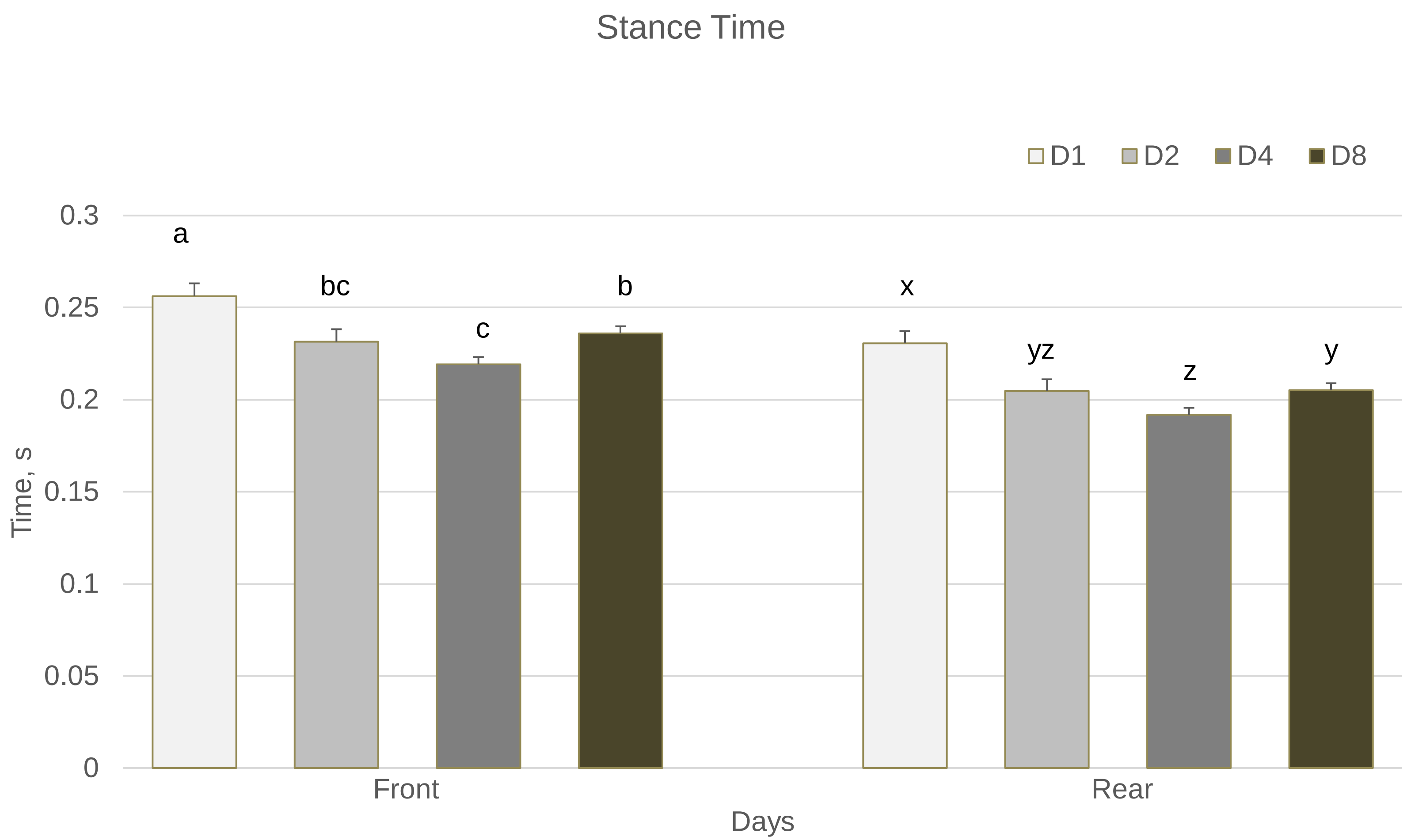
The letters signify P < 0.05 between the average means of the days.

Figure 3.6-Average swing time



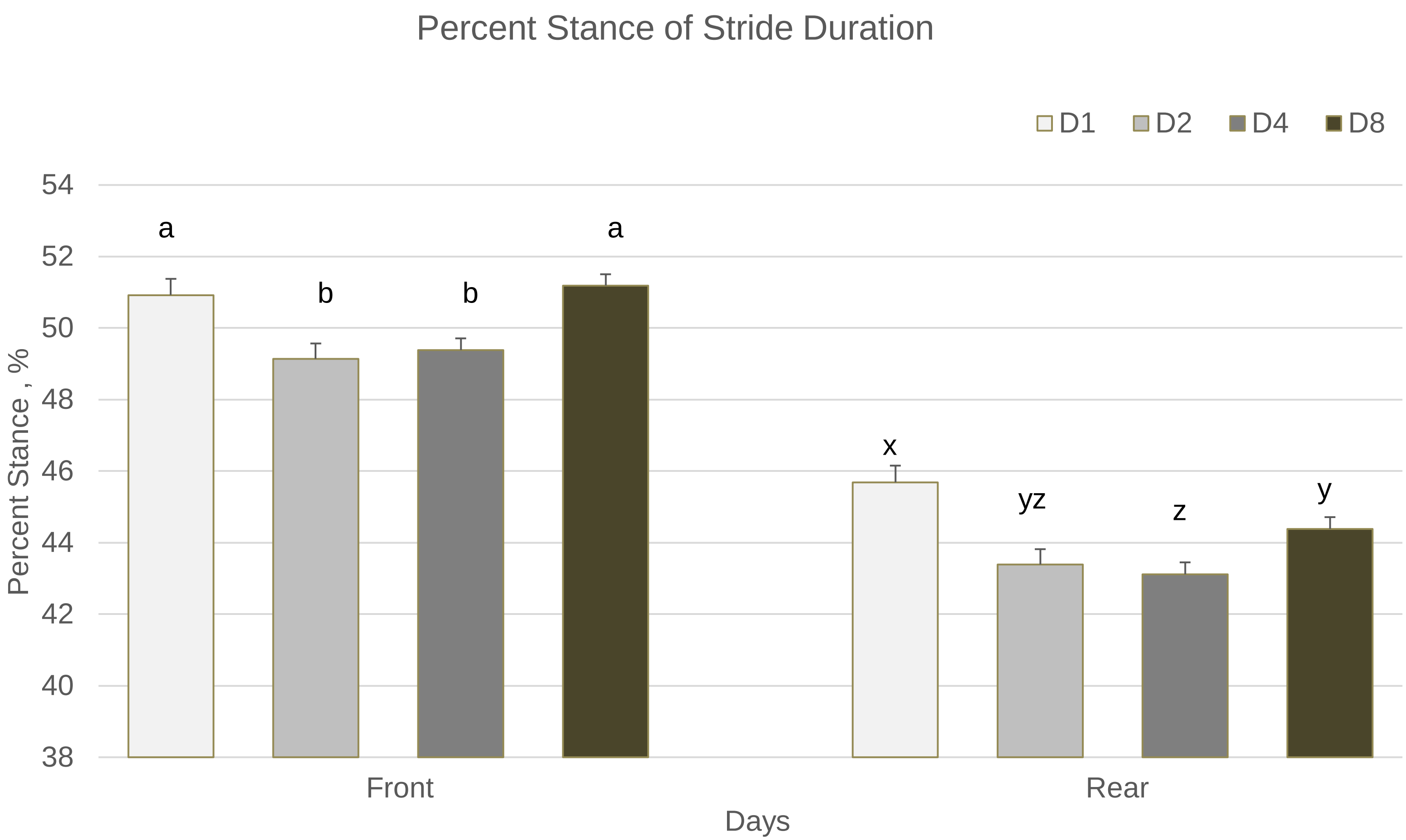
The letters signify P < 0.05 between the average means of the days.

Figure 3.7- Average stance time



The letters signify P < 0.05 between the average means of the days.

Figure 3.8- Average percent stance of stride duration



The letters signify $P < 0.05$ between the average means of the days.

CHAPTER 4

CHANGES IN KINEMATIC MEASUREMENTS FROM NURSERY THROUGH FINISHING FOR A MIXED GROUP OF PIGS

Introduction

Gait analysis has been shown to be an objective tool compared to traditional systems of lameness scoring, which are highly subjective with varying degrees of inter- and intra-observer correlation (Mohling et al., 2014). The systems that are used allow for less user error due to less control going to the user to define measurements. In cattle, like in pigs, normal gait qualities and variations are not well known as most gait analysis has been performed on lame animals (Wheeler et al., 2013). Studies are needed to focus on gait properties of sound animals in order to increase the detection and prevention of lameness. In horses and dogs, gait analysis has been used for years to improve welfare. In pigs, gait analysis is a relatively new tool.

In horse, it has been shown that the gait of a young horse can be predictive of the movements it will have as an adult (Clayton, 2004). Finding these gait qualities at a young age has been used to select high quality gaited horses to train for competitions. Gait analysis has also been used to help predict longevity of these horses based on the horse's movement and conformation (Wallin et al., 2003; Jönsson et al., 2014a) . Swing, along with certain joint angles have been shown to be the same in young Warmbloods and in adult (Back et al., 1995). These horse studies suggest that measurements can be found that will predict gait qualities in adult pigs based off of young pigs. For this study, the focus was on the kinematic measurements of the young pig's gait. The objective was to find parameters that could be predictive of gait across weight points.

Materials and Methods

Experimental protocols were approved by the University of Georgia (Athens, Ga) Institutional Animal Care and Use Committee (AUP#A2017 01-018-R1). Thirty-three, Choice Genetics cross pigs, 19 CG 32 by EB 5 pigs (10 females, 9 males) and 14 CG 32 by EB X sired pigs (8 females, 6 males) pigs were obtained around 10 kg from the University of Georgia Swine Unit. Pigs were brought into University of Georgia Large Animal Research Unit and given three days to adjust to their new surroundings before they were exposed to the track. EB X sired pigs are bred for rapid growth, while the EB 5 sired pigs bred for meat quality. None of the pigs were visibly lame at the start of the study. During the study, six pigs were removed prior to analysis. Three were removed due to lameness (2 EB 5 males, 1 EB X female), one died (EB 5 male), one was unthrifty (EB X male) and one had its data lost (EB X female). 11 of the remaining pigs lost one day (45 kg (1 EB 5 M), 68 kg (1 EB 5 F), 91kg (1 EB X female, 4 EB X male), and 113 kg (1 EB 5 female, 3 EB X female) due to inability to record for two weeks. No pig lost more than a day of data. Pigs were trained three times a week for at least two weeks to provide exposure to the mat before data collection started. At 23 kg, the pigs were recorded on the mat. Pigs were recorded at 23, 45, 68, 91, 113 and 136 kg for 6 repetitions at each weight. After data was collected, pigs are returned to their pens in the Large Animal Research Unit where they had ad libitum feed and water. Diets were changed to reflect weight and age group of the pigs (Table 4.1). After the study concluded, pigs were returned to the University of Georgia Swine Farm.

Pigs were walked back and forth through a dog bone track made of commercial hog panels across the 7.5 m GAITRite pressure mat (GAITRite, Franklin, New Jersey). Pigs were brought into the gait room from their pens one at a time. At each time point, the pigs were trotted across the pressure mat until 6 usable reps were obtained had passed from the start of the session. None of the pigs were on the mat for more than 20 minutes at a time.

Recorded Analysis

Recordings from the mat were collected in the GAIT4Dog software program (GAITRite, Franklin, New Jersey). This program provides a digital copy of the pig's footfalls as the land on the mat. The footfalls are then processed so that each one is numbered in the order they land. Once all feet are assigned a number, the program designates the foot that the footfall belongs to depending on direction of travel and pattern of movement so that each foot is categorized as right front, left front, right rear or left rear. Any erroneous assignments of number or foot assignment can be corrected by the user before the run is analyzed for gait parameters. Velocity, stance, swing, stride duration, stride length, and percent stance of stride duration were measured for each video. Measurements were compared over time.

Statistics

Data were analyzed in SAS (version 9.4; SAS Institute Inc., Cary, NC, USA) using a PROC MIXED procedure to evaluate the differences of the two paired limbs at the four time points as repeated measures. Time in seconds and distance in centimeters were the dependent variables of interest. Statistical significance was considered at $P < 0.05$ for all parameters measured, and PDIFF was used to separate means where necessary.

Results and Discussion

Velocity increased from 23 kg to 45 kg (P < 0.0001; Table 4.1, Figure 4.1), decreased from 45 kg to 68 and 91 kg (P < 0.0018; Table 4.1, Figure 4.1), decreased from 68 and 91 kg to 113 kg (P < 0.0021; Table 4.1, Figure 4.1), and increased from 113 to 136 kg (P < 0.03; Table 4.1, Figure 4.1). The 68, 91 and 136 kg velocities were not statistically different from the 23 kg velocity. Velocity only significantly varied at 45 kg and 113 kg, illustrating that across most weights, velocity should be maintained by the pig. The velocity change that we do see, does not appear to affect any of the other values, as the changes that were seen are not reflected in the other values. As is suspected in a growing animal, stride length increased as weight increased. Stride length increased from 23 kg to 113 to 136 kg (P < 0.0001; Table 4.1, Figure 4.2) for both front and rear limbs. Stride duration increased from 23 kg to 113 and 136 kg (P < 0.0001; Table 4.1, Figure 4.3) for both front and rear limbs.

Front swing increased from 23 kg to 136 kg (P< 0.0001; Table 4.1, Figure 4.4), with decreases from 68 kg to 91 kg (P < 0.0025; Table 4.1, Figure 4.4) and from 113 kg to 136 kg (P < 0.04; Table 4.1. Figure 4.4). Rear Swing increased from 23 and 45 kg to

136 kg ($P < 0.0001$; Table 4.1, Figure 4.4), with decreases from 68 kg to 91 kg ($P < 0.0001$; Table 4.1, Figure 4.4) and from 113 kg to 136 kg ($P < 0.02$; Table 4.1, Figure 4.4). While the patterns were seen in both front and rear limbs, the stride duration composition can be observed to be different from front to rear limbs. Front limb stride duration has a larger stance make up than swing, while rear limbs have a greater swing. This may be a reflection of the weight distribution across the limbs due to the extra weight of the head on the forelimbs (Jönsson et al., 2014b). Swing time increased across the weight points with dips at 91 and 136 kg. Stance time increased from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 4.1, Figure 4.5) from both front and rear limbs.

Stride duration increased across the weight points, with plateaus at 68 kg to 91 kg and 113 kg to 136 kg. The pattern of increasing across weights and plateauing at 68 kg to 91 kg and 113 kg to 136 kg that was observed in stride duration is reflected in the stance time. In horses, stride duration and stance time increased as the animal grew due to the increased protraction and retraction of the longer limb (Back et al., 1995). Percent stance increased from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 4.1, Figure 4.6). Stride duration, swing, stance and percent stance all increased across the weight points within groups which is supported by the findings in horses (Back et al., 1995).

Conclusion

This study illustrates the need for further studies into looking at predictive values within swine. From these results, no one parameter emerged as a constant across the weight points. The closest held value was swing, as is seen in horses, which is promising as values that are found in other species will be a good place to start for future studies.

Other parameters that were seen to increase in horses, such as stride duration and stance, increased in this study. This shows that while the results do not mirror those seen in the horse studies, the track that was taken may be the correct one in time. Unlike in horses, this study did not take into consideration the angles of joints, which will need to be investigated in future studies.

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Table 4.1- Nursery and grower diets

	Nursery			Grow-Finish	
Phase	I	II	III	G-1	G-2
Age, weeks Body weight, lb	3-4 10-15	4-6 15-25	6-8 25-55	8-12 55-110	12-16 110-170
Corn	40.56	49.71	64.06	60.43	60.65
DDGS	-	-	-	20.00	20.00
Whey	27.5	10.00	-	-	-
Soybean meal	16.78	31.55	30.82	14.41	15.76
Spray Dried Plasma Protein	5.0	-	-	-	-
Fat	1.65	2.26	1.35	2.34	1.00
Fish Meal	5.0	3.0	-	-	-
Dicalcium Phosphate	0.17	0.76	1.57	0.31	0.06
Limestone	0.88	0.87	0.84	1.11	1.60
Salt	0.20	0.25	0.35	0.35	0.35
Zinc Oxide	0.375	0.25	-	-	-
Vitamin premix	0.25	0.25	0.25	0.15	0.15
Mineral. Premix	0.15	0.15	0.15	0.15	0.15
Methionine	0.18	0.14	0.13	-	-
Lysine	0.30	0.30	0.40	0.40	0.29
Threonine	-	0.02	0.07	-	-
Antibiotic	1.00	0.50	-	-	-
Phytase	-	-	-	0.012	0.025
Calculated Analysis					
Energy, ME kcal/kg	3400	3400	3350	3400	3400
Crude Protein, %	22.18	21.74	20.71	16.3	13.6
Total Lysine, %	1.65	1.53	1.40	1.00	0.80
SID Lysine, %	1.50	1.35	1.23		
Calcium, %	0.85	0.80	0.75	0.75	0.70
Phosphorus, total %	0.65	0.58	0.41	0.65	0.60
Available, %	0.45	0.41	0.35	0.39	0.36

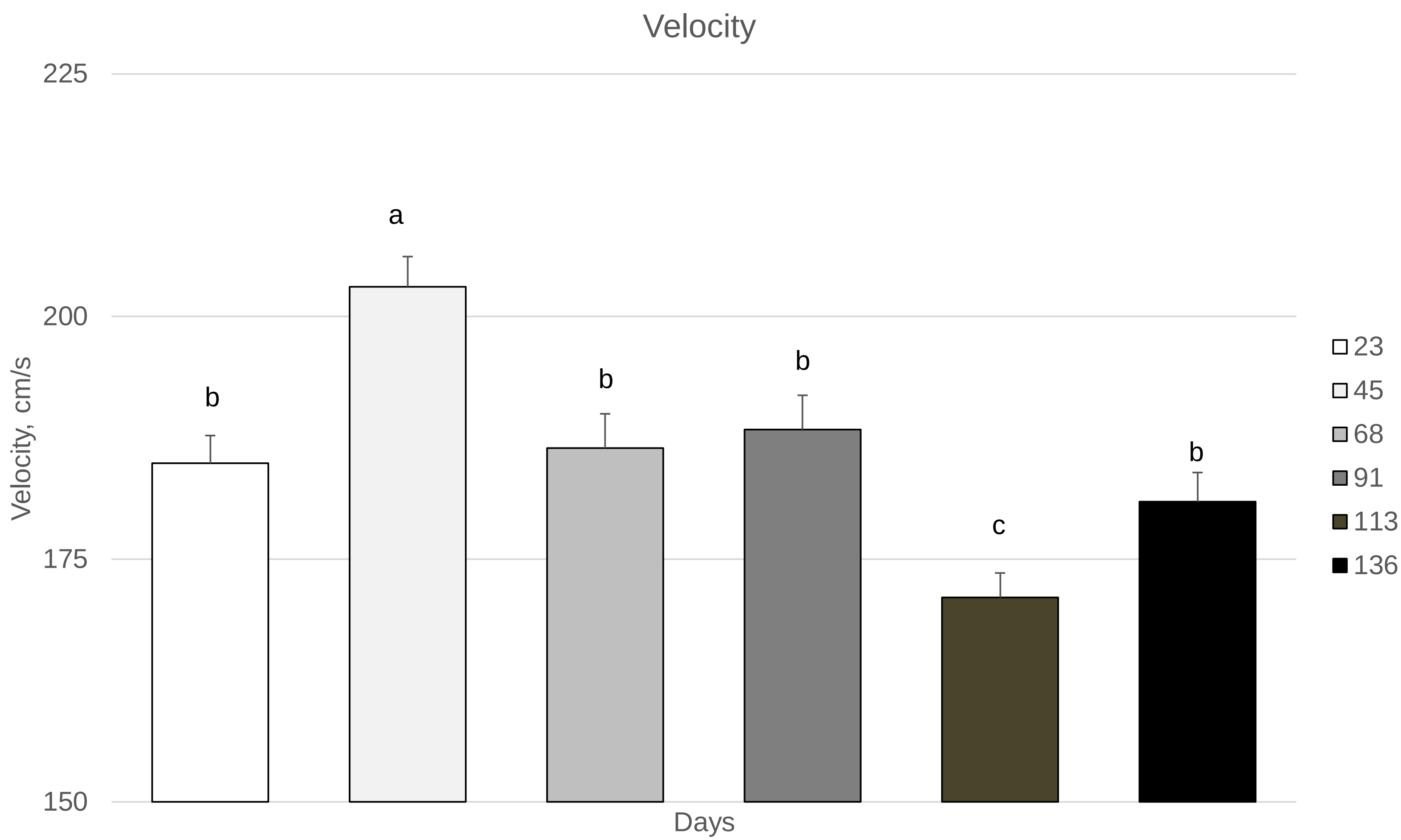
Diets for all pigs from beginning to end of study.

Table 4.2 -Weight points

Measurements	23	45	68	91	113	136
Velocity (cm/s)	184.89 ±2.85^{b}	203.07 ±3.11^{a}	186.45 ±3.53^{b}	188.36 ±3.53^{b}	171.06 ±2.52^{c}	180.93 ±3.00^{b}
Stride Length Front (cm)	67.67 ±0.62^{e}	80.13 ±0.62^{d}	84.65 ±0.69^{c}	85.73 ±0.78^{c}	88.20 ±0.77^{b}	91.60 ±0.57^{a}
Stride Length Rear (cm)	67.66 ±0.62^{e}	79.96 ±0.62^{d}	84.44 ±0.69^{c}	85.44 ±0.77^{c}	87.85 ±0.77^{b}	91.14 ±0.55^{a}
Stride Duration Front (s)	0.38 ±0.004^{d}	0.41 ±0.005^{c}	0.47 ±0.008^{b}	0.47 ±0.008^{b}	0.54 ±0.010^{a}	0.52 ±0.008^{a}
Stride Duration Rear (s)	0.38 ±0.004^{d}	0.41 ±0.005^{c}	0.47 ±0.008^{b}	0.47 ±0.008^{b}	0.54 ±0.009^{a}	0.52 ±0.008^{a}
Swing Time Front (s)	0.21 ±0.001^{e}	0.22 ±0.001^{d}	0.23 ±0.002^{b}	0.23 ±0.002^{c}	0.24 ±0.002^{a}	0.23 ±0.002^{b}
Swing Time Rear (s)	0.23 ±0.001^{e}	0.24 ±0.002^{d}	0.26 ±0.002^{b}	0.25 ±0.003^{c}	0.27 ±0.003^{a}	0.26 ±0.002^{b}
Stance Time Front (s)	0.16 ±0.004^{d}	0.19 ±0.004^{c}	0.24 ±0.007^{b}	0.25 ±0.007^{b}	0.30 ±0.008^{a}	0.29 ±0.007^{a}
Stance Time Rear (s)	0.14 ±0.003^{d}	0.17 ±0.004^{c}	0.21 ±0.006^{b}	0.22 ±0.006^{b}	0.27 ±0.008^{a}	0.27 ±0.007^{a}
Percent Stance Front (%)	42.37 ±0.41^{e}	45.04 ±0.41^{d}	49.66 ±0.41^{c}	51.27 ±0.46^{b}	54.34 ±0.49^{a}	54.64 ±0.38^{a}
Percent Stance Rear (%)	37.14 ±0.37^{e}	40.84 ±0.37^{d}	44.05 ±0.34^{c}	46.82 ±0.41^{b}	49.37 ±0.48^{a}	49.78 ±0.41^{a}

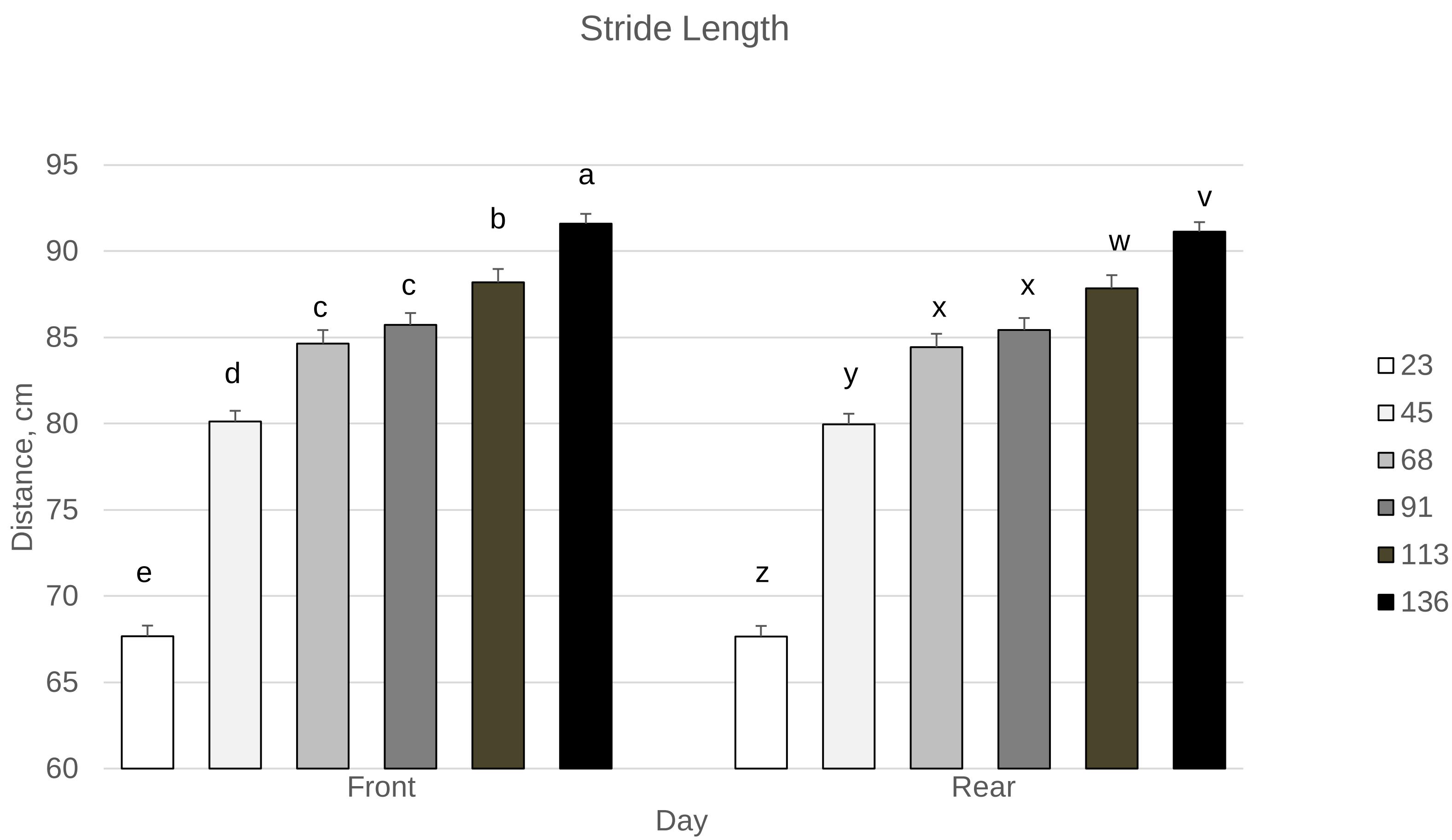
Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Figure 4.1- Average velocity



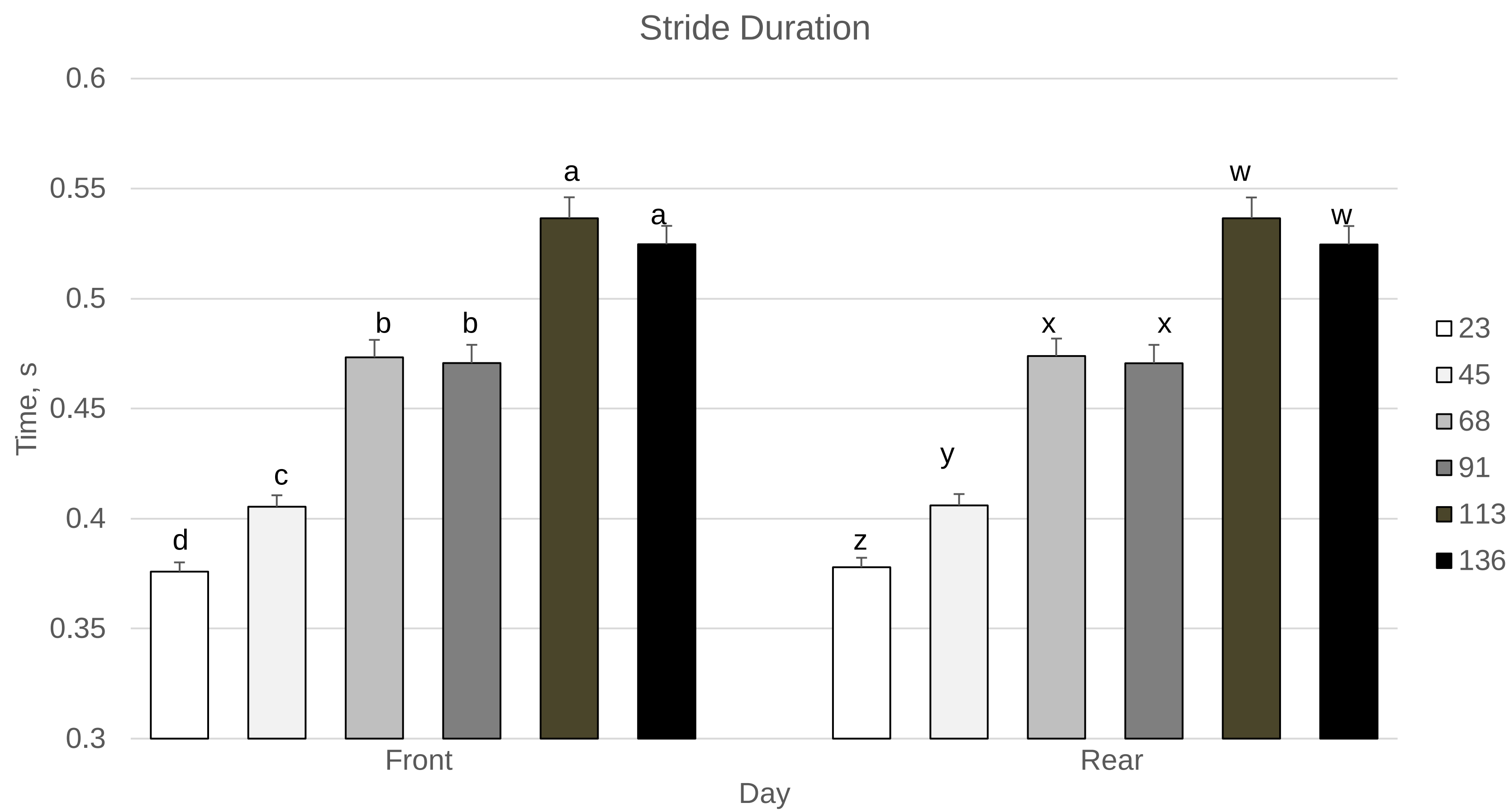
Difference in letters illustrates differences of P < 0.05 between the mean values of the days.

Figure 4.2- Average stride length



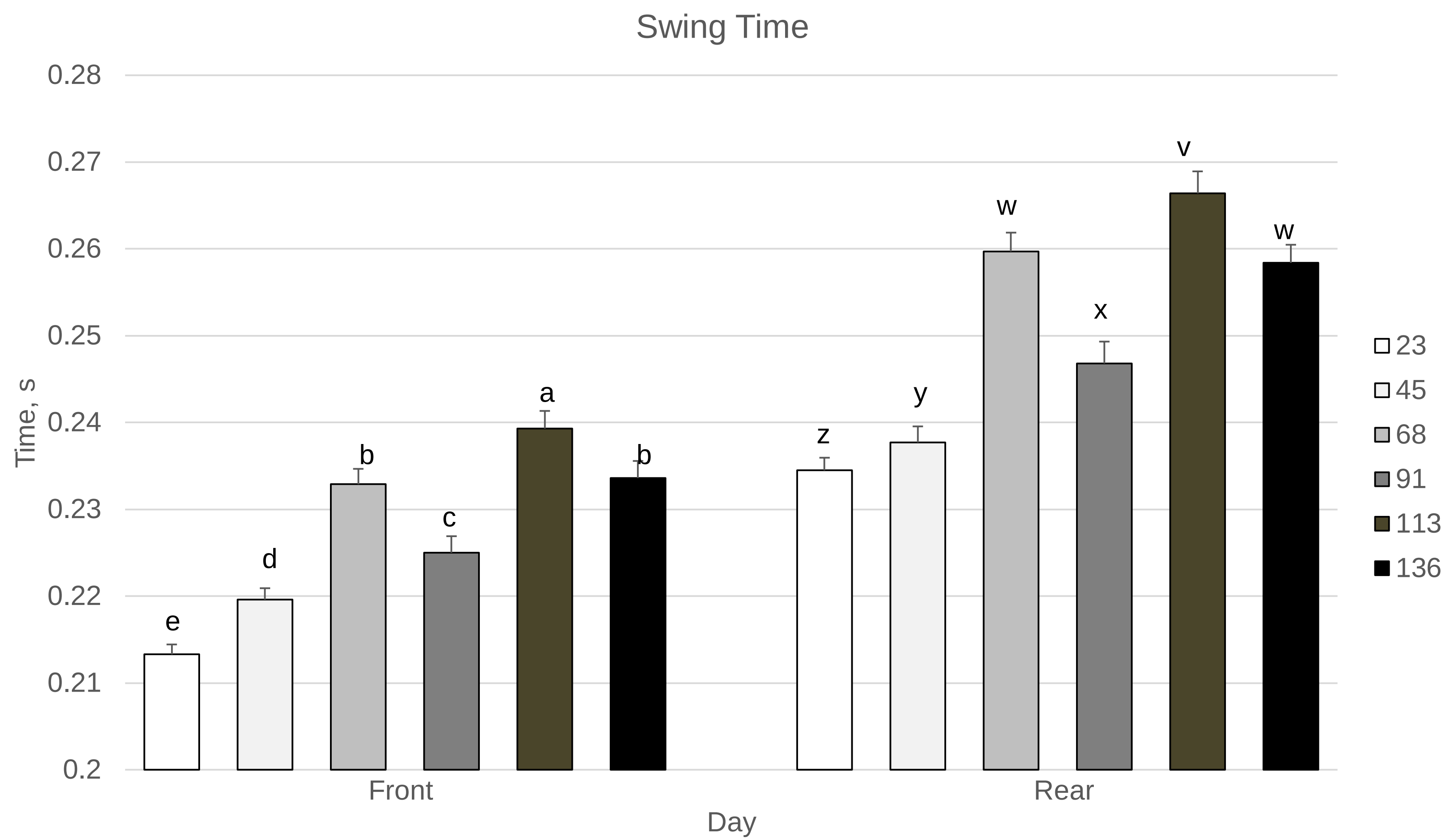
Difference in letters illustrates differences of P < 0.05 between the mean values of the days.

Figure 4.3- Average stride duration



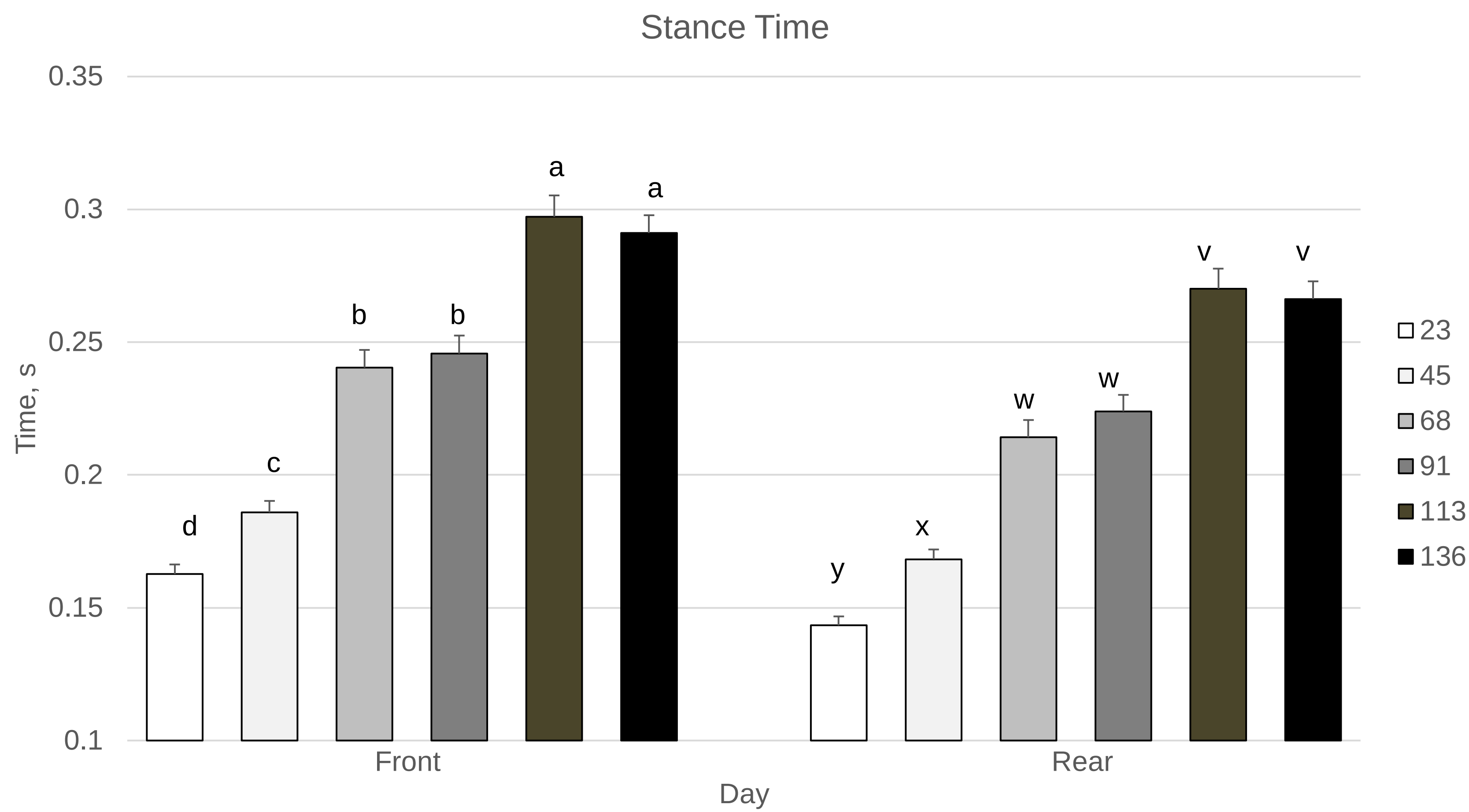
Difference in letters illustrates differences of P < 0.05 between the mean values of the days.

Figure 4.4- Average swing time



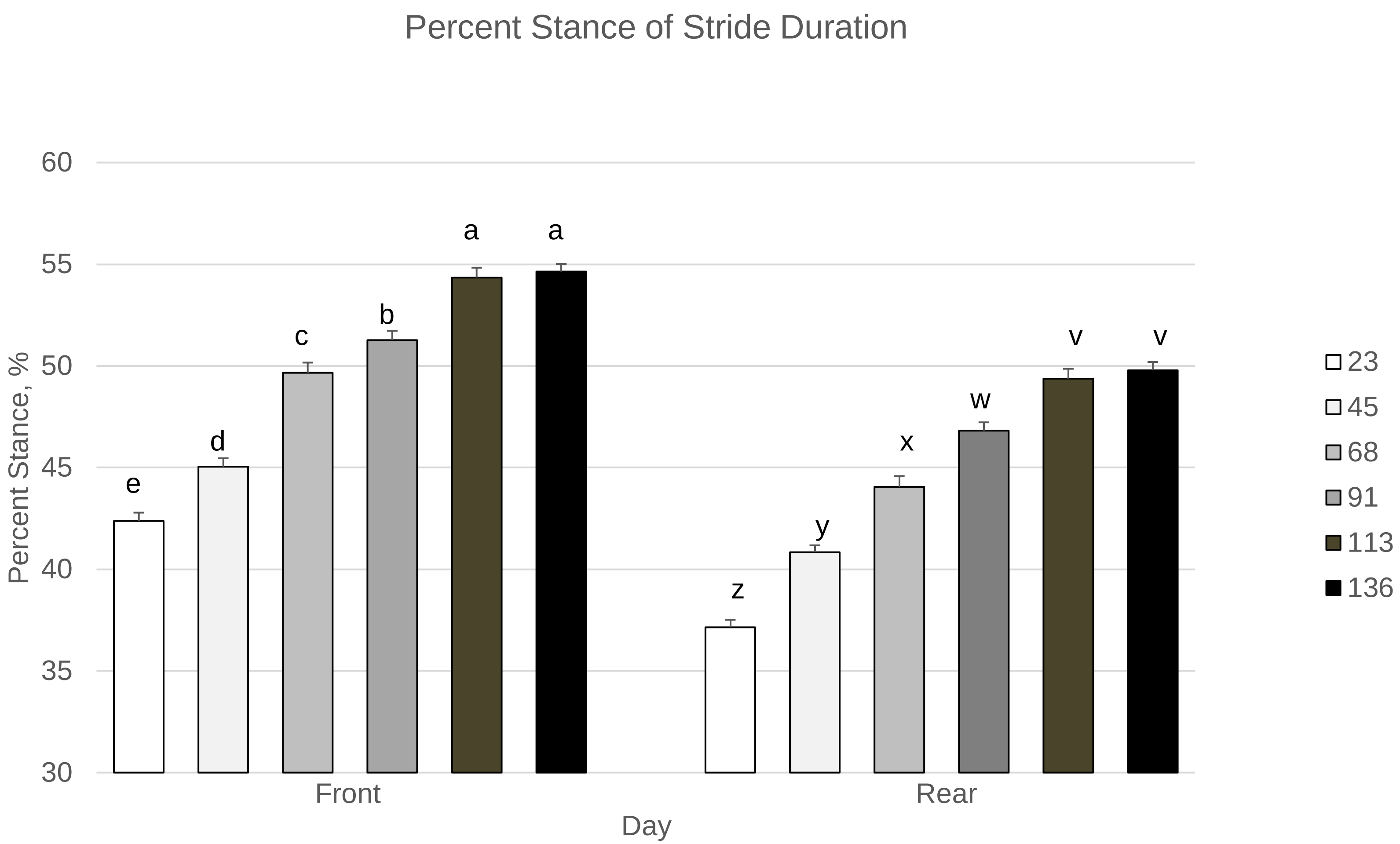
Difference in letters illustrates differences of P < 0.05 between the mean values of the days.

Figure 4.5- Average stance time



Difference in letters illustrates differences of $P < 0.05$ between the mean values of the days.

Figure 4.6- Average percent stance of stride duration



Difference in letters illustrates differences of P < 0.05 between the mean values of the days.

CHAPTER 5

DIFFERENCES IN GAIT DUE TO GENDER AND SIRE LINE IN TWO MIXED GROUPS OF GROWER PIGS

Introduction

Differences in behavior between the two genders has been documented across many species(Berenbaum et al., 2011). All types of behavior have been shown in humans to be influenced by genes, physiology and by the brain (Berenbaum et al., 2011. In cattle these differences in behavior are thought to be a reflection of temperament (Broucek et al., 2013a; Broucek et al., 2013b). In all species of animals, hormones cause permanent changes in behavior that dictate the differences in the genders (Berenbaum et al., 2011). These changes cause behavior to differ between females, intact males and castrated males. In cattle, females have been categorized as excitable or difficult to handle, with higher temperament scores than steers (Broucek et al., 2013b). This means when working with heifers, handlers had to be calmer and slower with their approach compared to steers. Yet, in Broucek et al, (2013b) heifers spent more time with new people compared to bulls. This is thought to be due to intact males being leerier of people than the females. This leeriness can be seen in horses as well with handlers categorizing yearling females as more skittish, suspicious and excitable compared to their males counterparts (Duberstein and Gilkeson, 2010). In pigs, castrated males have been thought to be victims of tail biting more often due to being more docile with age compared to females (Schrøder-Petersen et al., 2010). The females are thought to bite more often because they are generally more engaged in exploration and social behaviors (Schrøder-Petersen et al., 2010).

Part of temperament also can be a factor of genetics. Sire lineage has been shown to influence behavior of offspring in cattle (Broucek et al., 2013a). Some studies have indicated that cattle locomotor behavior is effected by genotypes (Broucek et al., 2013a; Broucek et al., 2013b). It has been illustrated that there are differences between sire lines in capability to learn (Broucek et al., 2013a). Sire lines in cattle were also shown to have significant behavior differences within an open-field test (Broucek et al., 2013b). Genotype has a significant effect on vocalization patterns, illustrating the variance in tameness due to genetics (Broucek et al., 2013b).

Materials and Methods

Experimental protocols were approved by the University of Georgia (Athens, Ga) Institutional Animal Care and Use Committee (AUP#A2017 01-018-R1).

Study 1

Thirty-one Choice Genetics pigs, which consisted of 16 CG 32 by EB 5 crosses (9 females, 7 males) and 15 CG 32 by EB X crosses (8 females and 7 males), were obtained at a weight of 68 +/- 5 kg from the University of Georgia Swine Unit. Pigs were brought into University of Georgia Large Animal Research Unit and given three days to adjust to their new surroundings before the study began. None of the pigs used were visually lame at the beginning of the study. Prior to the study none of the pigs had been familiarized to the gait mat. Training occurred in conjunction with recording, so that D1 of recording would also be the first day that the pigs were exposed to the mat. Pigs were trained on the mat on D1-D5 (Monday-Friday) and again on D8 (Monday). Pigs were recorded on D1, D2, D4 and D8 in conjunction with training. Pigs were encouraged to cross the mat using boards and sorting paddles, which would typically be used on a farm. No treats or rewards were used during the length of the study. For this study, we used the minimum amount of stimulus to have pigs to successfully cross the track. First, paddles were used as shakers behind the pig to send them forward. Then paddles were tapped against the fencing near the pig's hindquarters. When noise did not have an effect, then pigs were tapped on their rump in an increasing rate until they moved forwards. If pigs did not respond or fought against the stimulus, they were given a minute to rest before the stimulus was reinstated along with a board, which was added to funnel their movement forward towards the mat. For every repetition across the mat, the process was repeated so that the minimum stimulus was used and that pigs would have the least amount of interference possible.

Pigs were walked back and forth through a dog bone track made of commercial hog panels across a 7.5 m GAITRite pressure mat (GAITRite, Franklin, New Jersey). Pigs were brought into the gait room from their pens one at a time. At each time point, the pigs were moved across the pressure mat in a diagonal pair footfall until 6 usable repetitions were obtained or a maximum of twenty minutes had passed from the start of the session. Each run was recorded and processed at a later time. After data were collected, pigs were returned to their pens in the Large Animal Research Unit, where they had access to ad libitum feed and water. Diets were changed to reflect weight and age group of the pigs

(Table 5.1). At the end of the study, pigs were returned to the University of Georgia Swine Farm.

Study 2

Twenty-seven, Choice Genetics cross pigs, 16 CG 32 by EB 5 pigs (10 females, 6 males) and 11 CG 32 by EB X sired pigs (6 females, 5 males) pigs were obtained around 10 kg from the University of Georgia Swine Unit. Pigs were brought into University of Georgia Large Animal Research Unit and given three days to adjust to their new surroundings before they were exposed to the track. Pigs were trained three times a week for at least two weeks to provide exposure to the mat. At 23 kg, the pigs were recorded on the mat. Pigs were recorded at 23, 45, 68, 91, 113 and 136 kg for 6 repetitions at each weight. After data was collected, pigs are returned to their pens in the Large Animal Research Unit where they had ad libitum feed and water. After the study concluded, pigs were returned to the University of Georgia Swine Farm.

Pigs were walked back and forth through a dog bone track made of commercial hog panels across the 7.5 m GAITRite pressure mat (GAITRite, Franklin, New Jersey). Pigs were brought into the gait room from their pens one at a time. At each time point, the pigs were trotted across the pressure mat until 6 usable reps were obtained had passed from the start of the session. None of the pigs were on the mat for more than 20 minutes at a time. After data were collected, pigs were returned to their pens in the Large Animal Research Unit, where they had access to ad libitum feed and water. Diets were changed to reflect weight and age group of the pigs (Table 5.1). At the end of the study, pigs were returned to the University of Georgia Swine Farm.

Recorded Analysis

Recordings from the mat for both studies were collected in the GAIT4Dog software program (GAITRite, Franklin, New Jersey). This program provides a digital copy of the pig's footfalls as they land on the mat. The footfalls are then processed so that each one is numbered in the order they land. Once all feet are assigned a number, the program designates the foot that the footfall belongs to depending on direction of travel and pattern of movement so that each foot is categorized as right front, left front, right rear or left rear. Any erroneous assignments of number or foot assignment can be corrected by the user before the run is analyzed for gait parameters. Velocity, stance, swing, stride duration, stride length, and percent stance of stride duration were measured for each video and was recorded for gait parameters. Measurements were statistically compared across the time points.

Statistics

Data were analyzed for both studies in SAS (version 9.4; SAS Institute Inc., Cary, NC, USA) using a PROC MIXED procedure to evaluate the differences of the front and rear limbs at the four time points as a repeated measures model. All variables mentioned above were compared at each time point. Statistical significance was considered at $P < 0.05$ for all parameters measured, and PDIFF was used to separate means where necessary.

Results

Study 1

Gender by Day

Velocity increased in females from D1 to D2 and D4 ($P < 0.01$; Table 5.1) and decreased from D2 and D4 to D8 ($P < 0.02$; Table 5.1). Males had an increase in velocity from D1 to D4 and D8 ($P < 0.03$; Table 5.2). Females had a higher velocity than males for D1, D2 and D4 ($P < 0.01$; Table 5.1 and 5.2). Stride length was greater for females compared to males across all days ($P < 0.04$; Table 5.1 and 5.2). Stride duration decreased in females from D1 to D2 and D4 ($P < 0.04$; Table 5.1) and increased from D4 to D8 ($P < 0.02$; Table 5.1). In males, stride duration decreased from D1 to D4 and D8 and from D2 to D4 ($P < 0.02$; Table 5.2). Females had a decreased stride duration compared to males on D1 and D2 ($P < 0.02$; Table 5.1 and 5.2).

Percent stance decreased in rear limbs of females from D1 to D2 and D4 ($P < 0.003$; Table 5.1) and increased from D2 to D8 for front limbs ($P < 0.001$; Table 5.1). There was an increase in percent stance in females from D4 to D8 in all four limbs ($P < 0.05$; Table 5.1). There was a decrease in percent stance for males from D1 to D2 and D4 ($P < 0.04$; Table 5.2). There was an increase from D2 and D4 to D8 in front limbs of males ($P < 0.03$; Table 5.2). Females had smaller percent stance than males for all days ($P < 0.0005$; Table 5.1 and 5.2).

Sire by Day

There was an increase in velocity for EB 5 from D1 to D4 ($P < 0.002$; Table 5.3). There was a decrease in velocity for EB X sired pigs from D1 to D2 and D4 ($P < 0.01$;

Table 5.4). There was a decrease in velocity in EB X sired pigs from D2 to D8 ($P < 0.006$; Table 5.4). From D2 to D4 and from D4 to D8 for EB 5 pigs, there was an increase in velocity ($P < 0.02$; Table 5.3). There was an increase in velocity from EB 5 pigs to EB X sired pigs on D2 ($P < 0.0008$; Table 5.3 and 5.4). Stride length increased in EB X sired pigs from D1 to D2 ($P < 0.001$; Table 5.4). Stride length was decreased in rear limbs from D2 to D4 and all limbs from D2 to D8 ($P < 0.02$; Table 5.4) in EB X sired pigs. EB 5 pigs had a smaller stride length than EB X sired pigs on D2 ($P < 0.0002$; Table 5.3 and 5.4).

Stride duration decreased for EB 5 pigs from D1 to D4 and D8 ($P < 0.001$; Table 5.3) and D2 to D4 ($P < 0.006$; Table 5.3). There was an increase in stride duration from D4 to D8 for EB 5 pigs ($P < 0.01$; Table 5.3). For EB X sired pigs stride duration, there was a decrease from D1 to D2 and D4 ($P < 0.01$; Table 5.4). EB 5 pigs had longer stride durations than EB X sired pigs on D2 ($P < 0.006$; Table 5.3 and 5.4).

The percent stance for EB 5 pigs decreased from D1 to D4 in all four limbs ($P < 0.02$; Table 5.3) and from D2 to D4 in rear limbs ($P < 0.02$; Table 5.3). There was an increase in EB 5 pigs' percent stance from D4 to D8 ($P < 0.01$; Table 5.3). For EB X sired pigs, percent stance decreased from D1 to D2 ($P < 0.001$; Table 5.4) in all four limbs and D1 to D4 ($P < 0.02$; Table 5.4) in the rear limbs. For EB X sired pigs, there was an increase in front limb percent stance from D2 to D4 ($P < 0.02$; Table 5.4), an increase in all limbs from D2 to D8 ($P < 0.007$; Table 5.4), and an increase in front limbs from D4 to D8 ($P < 0.03$; Table 5.4). There was an increased percent stance for front limbs EB 5 pigs compared to EB X sired pigs front limbs on D2 ($P < 0.0009$; Table 5.3 and 5.4). There was also a decrease percent stance from EB 5 pigs compared to rear limbs of EB X sired pigs on D4 to D8 ($P < 0.03$; Table 5.3 and 5.4).

Study 2

Gender by Weight

Velocity decreased for females from 45 kg to 68, 91, 113 and 136 kg ($P < 0.02$; Table 5.5), but the only weight point that was statically different from 23 kg is 113 kg ($P < 0.003$, Table 5.5). Male velocity increased from 23 kg to 45 kg ($P < 0.0001$; Table 5.6), decreased from 45 kg to 68 and 91 kg ($P < 0.04$; Table 5.6), and decreased from 68 and 91 kg to 113 kg ($P < 0.003$; Table 5.6). 23 kg and 136 were not statistically different from each other ($P=0.14$; Table 5.6). Females had statistically larger velocities than males at 23 and 113 kg ($P < 0.005$; Table 5.5 and 5.6). Front stride length for females increased from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 5.5). Males had an increase in both front and rear stride length from 23 kg to 136 kg ($P < 0.0001$; Table 5.6). For both front and rear limbs, females had the longer stride length at 23 and 113 kg compared to males ($P < 0.02$; Table 5.5 and 5.6). Females also had a higher front stride length at 91 kg compared to males ($P < 0.04$; Table 5.5 and 5.6).

Stride duration increased for females from 23 kg to 45 kg ($P < 0.0001$; Table 5.5), increased from 45 kg to 113 and 136 kg ($P < 0.0001$; Table 5.5). Males had a stride duration that increased from 23 and 45 kg to 136 kg ($P < 0.0001$; Table 5.6), with a decrease from 113 kg to 136 kg ($P < 0.03$; Table 5.6). Males had significantly longer stride duration compared to females at 23, 68 and 113 kg ($P < 0.04$; Table 5.5 and 5.6). Front swing for females increases from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 5.5). Rear swing for females increased from 23 and 45 kg to 113 and 136 kg ($P < 0.0001$; Table 5.5). Males had an increase from 23 and 45 kg to 136 kg ($P < 0.0001$; Table 5.6), with a decrease from 68 kg to 91 kg ($P < 0.0001$; Table 5.6) and from 113 kg to 136 kg ($P < 0.04$; Table 5.6). Females had shorter front swing at 68 kg ($P < 0.0008$; Table 5.5 and 5.6) and a shorter rear swing at 68, 113 and 136 kg compared to males ($P < 0.04$; Table 5.5 and 5.6).

Front stance in females increased from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 5.5). Rear stance for females increased from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 5.5). Males saw an increase from 23 and 45 kg to 136 kg ($P < 0.0001$; Table 5.6) with a decrease from 113 kg to 136 kg ($P < 0.04$; Table 5.6) in stance for both front and rear limbs. Comparing stance for females and males, males had longer stance for 23 and 113 kg ($P < 0.001$; Table 5.5 and 5.6). Females had an increase in front percent stance from 23 kg to 136 kg ($P < 0.0001$; Table 5.5). Rear percent stance increased for females from 23 kg to 136 kg ($P < 0.0001$; Table 5.5). Males saw an increase in front percent stance from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 5.6). When compared, males had larger percent stance than females for 23 and 113 kg ($P < 0.02$; Table 5.5 and 5.6).

Sire by Weight

For EB 5 pigs, velocity increased from 23 kg to 45 kg ($P < 0.004$; Table 5.7), then decreased from 45 kg to 68, 91, 113 and 136 kg ($P < 0.004$; Table 5.7). EB X sired pigs had an increase from 23 kg to 136 kg ($P < 0.0001$; Table 5.8) with decreases from 45 kg to 68 kg ($P < 0.03$; Table 5.8), and from 68 and 91 kg to 113 kg ($P < 0.003$; Table 5.8). Velocity was higher for EB X at 91 and 136 kg than EB 5 ($P < 0.02$; Table 5.7 and 5.8). Stride length for EB 5 increased from 23 kg to 113 and 136 kg ($P < 0.0001$; Table 5.7). EB X stride length increased from 23 kg to 136 kg ($P < 0.0001$; Table 5.8). EB X had a longer front stride length than EB 5 across all days (P < 0.03; Table 5.7 and 5.8). Rear stride length for EB 5 increased from 23 kg to 113 and 136 kg (P < 0.0001; Table 5.7). EB X rear stride length increased from 23 kg to 136 kg (P < 0.0001; Table 5.8). EB X sired pigs had longer rear stride length than EB 5 pigs at 23 and 113 kg (P < 0.02; Table 5.7 and 5.8).

Stride duration increased for EB 5 pigs from 23 kg to 113 and 136 kg (P < 0.0001; Table 5.7). EB X pig's stride duration increased from 23 kg to 136 kg (P < 0.0001; Table 5.8). EB X sired pigs had higher front stride durations at 23 and 113 kg compared to the EB 5 pigs (P < 0.01; Table 5.7 and 5.8). EB 5 pigs rear stride duration increased from 23 kg to 113 and 136 kg (P < 0.0001; Table 5.7). Rear stride duration for EB X sired pigs increased from 23 and 45 kg to 136 kg (P < 0.0001; Table 5.8) with a decrease from 113 kg to 136 kg (P < 0.01; Table 5.8). EB X had higher stride duration at 23 kg and 113 kg (P < 0.02; Table 5.7 and 5.8) than EB 5 pigs, while EB 5 pigs had a higher rear stride duration at 136 kg (P < 0.04; Table 5.7 and 5.8). EB 5 pigs front swing increased from 23 kg to 136 kg (P < 0.0001; Table 5.7) with a decrease from 68 kg to 91 kg (P < 0.001; Table 5.7). EB X sired pigs front swing increased from 23 and 45 kg to 136 kg (P < 0.0001, Table 5.8) with a decrease from 113 kg to 136 kg (P < 0.002; Table 5.8). EB X sired pigs had a higher front swing time at 23, 45, 91 and 113 kg (P < 0.0002; Table 5.8). Rear swing for EB 5 pigs increased from 23 and 45 kg to 136 kg (P < 0.0001; Table 5.7) with a decrease from 68 kg to 91 kg (P < 0.0001; Table 5.7). Rear swing for EB X sired pigs increased from 23 and 45 kg to 136 kg (P < 0.0001; Table 5.8), with a decrease from 113 kg to 136 kg (P < 0.0008; Table 5.8). EB X sired pigs had longer swing compared to EB 5 across all weight points (P < 0.08; Table 5.7 and 5.8).

Front stance for EB 5 pigs increased from 23 kg to 136 kg (P < 0.0001; Table 5.7). Front stance for EB X sired pigs increased from 23 and 45 kg to 136 kg (P < 0.0001; Table 5.8), with a decrease from 113 to 136 kg (P < 0.02; Table 5.8). EB X had longer front swing at 23 kg and a shorter front swing at 136 kg (P < 0.002; Table 5.7 and 5.8) than EB 5 pigs. Rear stance for EB 5 pigs increased from 23 kg to 136 kg (P < 0.0001; Table 5.7). EB X sired pigs rear stance increased from 23 kg to 136 kg (P < 0.0001; Table 5.8). EB X sired pigs had a higher rear stance at 23 kg and was a smaller rear stance at 136 kg compared to EB 5 pigs (P < 0.02; Table 5.7 and 5.8). Percent stance for EB 5 pigs increased from 23 kg to 136 kg (P < 0.0001; Table 5.7). Front EB X sired pigs for percent stance increased from 23 kg to 113 and 136 kg (P < 0.0001; Table 5.8). Rear percent stance for EB X sired pigs increased from 23 kg to 113 and 136 kg (P < 0.0001; Table 5.8). EB 5 pigs had a greater front percent stance compared to EB X sired pigs at 136 kg (P < 0.0001; Table 5.7). EB 5 pigs also had a greater rear percent stance at 45, 68, 91 and 136 kg (P < 0.006; Table 5.7 and 5.8) than EB X sired pigs.

Discussion

Both of these studies illustrated that females moved out across the mat more efficiently compared to males. In the training study, it is due to their higher velocity and longer stride length. Stride length across the days for both males and females did not change across the days. For stride length in the training study, the females moved across the mat with a longer stride length than the males, showing that they were more efficient crossing the mat.

The decrease in stride duration from D1 to D4 in the training study shows that as the week progressed, both males and females moved across the mat more efficiently. Stride duration increased for both males and females on D8, showing that the two-day break causes a loss of improvement in the gait. Females moved out more than males on D1 and D2, showing that they naturally move across the same distance in a shorter time, but that by D4 and D8 males have enough training that the difference is negligible. While both percent stance and swing decrease from D1 to D4, the stance decreased more than swing. This shows that there was improvement in gait quality, since more of the stride duration is spend in the forward movement of the limb. For both genders, the data also shows that on D8 percent stance returned back to what was seen on D1. In four-month old Warmblood foals, gender impacts the daily activities and interactions to reflect behaviors that will be seen later in life (Kurvers et al., 2006). The difference in behavior between the two genders may explain why training has a different effect on the two genders. Another way to interpret this data is that the females were more skittish of handlers, which caused them to be easier to move across the mat.

In the growing study, difference between the two genders are seen from the first weight point of 23 kg. At 23 kg, females compared to males had a larger velocity, longer stride length, shorter stride duration, shorter stance time and smaller percent stance. This shows that from the beginning, the females presented a higher quality gait compared to the males. Yet, this could be a false comparison as males provided more resistance to moving across the mat from the beginning, which instead shows the difference in temperament. This difference in behavior could stem from the differences in personality between the two genders, with the females being flightier and therefore less willing to allow a hander near them. In a study that surveyed handlers of yearling horses, females were shown to be more skittish, suspicious and excitable compared to males (Duberstein and Gilkeson, 2010). Being more skittish would cause a larger flight zone in the pigs, allowing for less stimulus to be needed to persuade the pig to break out into a diagonal pair gait.

At 68 kg, females had a shorter stride duration and swing time compared to males. This could be illustrating the differences in limb length between the two genders, causing the same differences that we saw that were due to growth. Females had a longer front stride length and a shorter percent stance compared to males at 91 kg. Females had an increased velocity, longer stride length, shorter stride duration, shorter rear swing compared to males at 113 kg. In Warmblood foals, it has been shown that females have a higher percentage of premium status scores (Bhatnagar et al., 2011). This score in combination with the females higher score for type and conformation, overall development as related to age and total score (Bhatnagar et al., 2011) shows that there is difference in gender for conformation, development and quality of movement. At 136 kg, rear swing was shorter for females compared to males.

In both studies, the EB X sired pigs showed improved gait compared to the EB 5 sired pigs. For the training study, velocity increased and then returned to original levels across the days, showing that training increased the pigs speed of moving forward and the two-day break regressed the pace back to original values. EB X sired pigs were faster on D2 but otherwise reflect the EB 5 pigs' pace. Stride length was longer for EB X sired pigs, showing that they moved out across the mat more efficiently on D2. D2 also had the longest stride length, with D8 regressing back to D1 stride lengths. Both lines of pigs decreased their stride duration, showing that as they were exposed to the mat, they moved across the mat more quickly. On D2, the stride duration for EB X sired pigs was shorter than EB 5 sired pigs, which is linked to the difference in velocity. Stride duration increased on D8, showing that there was loss in training over the two days off. Percent stance shows that training decreased the percent of time the pigs were in stance versus moving through the swing. After the break in training, the percent stance increased back to initial values. Front percent stance on D2 was lower for EB X sired pigs, which linked towards the difference in velocity. Rear percent stance was greater for EB X sired pigs on D4 and D8, which shows that EB 5 sired pigs were more efficient in their gait as they spend less time in stance during their stride duration.

In the growing study, both EB 5 sired pigs and EB X sired pigs maintained velocities that were close to each other across the weight points, with EB X sired pigs reflecting what was seen in the day results. Stride length increased with plateaus at 68 and 91 kg and at 113 and 136 kg for EB 5 pigs. EB X stride length increased across the weight points with a plateau at 68 to 113 kg. Both sire lines had an increased stride duration as they grew across the weight points. The small range of swing shows that while the differences were significantly different, swing was maintained closer than any other measurement. EB X sired pigs had an increased stride duration compared to EB 5 pigs. This in conjunction with the longer swing time, created the shorter stance as a percent of stride duration for the EB X sired pigs,

Velocity was higher for EB X sired pigs compared to EB 5 pigs at 91 and 136 kg. For all weight points EB X sired pigs had longer stride lengths compared to EB 5 pigs. Stride duration was increased for EB X sired pigs at 23 and 113 kg for both front and rear limbs compared to EB 5 pigs. Rear stride duration was also longer for EB 5 pigs at 136 kg. Swing time was higher in front and rear limbs at 23, 45, 91, and 113 kg for EB X sired pigs compared to EB 5 pigs. Rear swing time was higher for EB X sired pigs compared to EB 5 pigs at 91 kg. Stance time was higher for EB X sired pigs at 23 kg compared to EB 5 pigs, while EB 5 pigs had a higher stance time at 136 kg compared to EB X sired pigs. Percent stance was greater for EB 5 pigs compared to EB X sired pigs for rear limbs at 45, 68, and 91 kg, and all limbs at 136 kg.

Conclusion

Having notable differences in the locomotion due to gender and sire line genetics shows that animals not only move differently across the mat but also that they will respond differently to the pressure that is put on them. Changes showed that gender and sire have an effect not only on training effects, but also on the starting point that the pigs are at in the beginning of training. The difference in handling based on gender and genetic lines may also be necessary for commercial settings as well to increase efficiency when moving, loading trailers, or unloading trailers. Further studies should be run to see if any other lines of pigs have strong dichotomies in gait quality that need to be assessed so that handlers can work with both genders efficiently. Future studies may also want to determine if any change would be notable after a more training.

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Table 5.1- Nursery and Grower Diet

	Nursery			Grow-Finish	
Phase	I	II	III	G-1	G-2
Age, weeks Body weight, lb	3-4 10-15	4-6 15-25	6-8 25-55	8-12 55-110	12-16 110-170
Corn	40.56	49.71	64.06	60.43	60.65
DDGS	-	-	-	20.00	20.00
Whey	27.5	10.00	-	-	-
Soybean meal	16.78	31.55	30.82	14.41	15.76
Spray Dried Plasma Protein	5.0	-	-	-	-
Fat	1.65	2.26	1.35	2.34	1.00
Fish Meal	5.0	3.0	-	-	-
Dicalcium Phosphate	0.17	0.76	1.57	0.31	0.06
Limestone	0.88	0.87	0.84	1.11	1.60
Salt	0.20	0.25	0.35	0.35	0.35
Zinc Oxide	0.375	0.25	-	-	-
Vitamin premix	0.25	0.25	0.25	0.15	0.15
Mineral. Premix	0.15	0.15	0.15	0.15	0.15
Methionine	0.18	0.14	0.13	-	-
Lysine	0.30	0.30	0.40	0.40	0.29
Threonine	-	0.02	0.07	-	-
Antibiotic	1.00	0.50	-	-	-
Phytase	-	-	-	0.012	0.025
Calculated Analysis					
Energy, ME kcal/kg	3400	3400	3350	3400	3400
Crude Protein, %	22.18	21.74	20.71	16.3	13.6
Total Lysine, %	1.65	1.53	1.40	1.00	0.80
SID Lysine, %	1.50	1.35	1.23		
Calcium, %	0.85	0.80	0.75	0.75	0.70
Phosphorus, total %	0.65	0.58	0.41	0.65	0.60
Available, %	0.45	0.41	0.35	0.39	0.36

Diets for all pigs from beginning to end of study

Table 5.2- Gender by day for study 1 females

Measurements	F D1	F D2	F D4	F D8
Total Time on mat (min)	7.15 ±1.05^{a}	5.36 ±0.92^{ab}	4.31 ±0.75^{b}	4.49 ±0.89^{ab*}
Time to First Usable Run (min)	2.05 ±0.59	0.94 ±0.36*	0.87± 0.33	1.74 ±0.52
Total Runs	15.88 ±1.25	15.64 ±1.41	15.60 ±1.48	16.58 ±1.51
Velocity (cm/s)	188.47 ±4.49 ^{b*}	204.15 ±4.40 ^{a*}	204.54 ±3.28 ^{a*}	192.23 ±3.24 ^{b}
Stride Length Front (cm)	85.32 ±0.79*	86.76 ±0.75*	86.10 ±0.71*	85.17 ±0.63*
Stride Length Rear (cm)	85.16 ±0.80*	86.50 ±0.74*	85.93 ±0.71*	84.99 ±0.61*
Stride Duration Front (s)	0.47 ±0.01^{a*}	0.44 ±0.01^{bc*}	0.43 ±0.006^{c}	0.45 ±0.006^{ab}
Stride Duration Rear (s)	0.47 ±0.01^{a*}	0.43 ±0.01^{bc*}	0.43 ±0.006^{c}	0.45 ±0.007^{ab}
Swing Time Front (s)	0.23 ±0.002^{a}	0.23 ±0.002^{b}	0.22 ±0.002^{b*}	0.22 ±0.002^{b*}
Swing Time Rear (s)	0.26 ±0.003^{a}	0.25 ±0.003^{bc}	0.25 ±0.002^{c}	0.26 ±0.002^{ab*}
Stance Time Front (s)	0.23 ±0.009^{a*}	0.21 ±0.01^{ab*}	0.21 ±0.005^{b*}	0.23 ±0.005^{a*}
Stance Time Rear (s)	0.21 ±0.009^{a*}	0.18 ±0.009^{bc*}	0.18 ±0.005^{c*}	0.20 ±0.005^{ab*}
Percent Stance Front (%)	49.04 ±0.61^{ab*}	47.36 ±0.61^{b*}	47.74 ±0.44^{b*}	49.77 ±0.44^{a*}
Percent Stance Rear (%)	44.05 ±0.63^{a*}	41.47 ±0.61^{bc*}	41.43 ±0.45^{c*}	42.70 ±0.45^{ab*}

Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Asterisks denote differences of $P < 0.05$ for the value between the genders.

Table 5.3- Gender by day for study 1 males

Measurements	M D1	M D2	M D4	M D8
Total Time on mat (min)	7.71 ±1.15	7.00 ±1.01	5.93 ±0.83	7.21 ±0.97[*]
Time to First Usable Run (min)	2.36 ±0.65	2.36 ±0.40[*]	1.50 ±0.36	1.71 ±0.57
Total Runs	17.07 ±1.38	18.43 ±1.55	15.57 ±1.62	17.79 ±1.67
Velocity (cm/s)	172.13 ±4.96[b*]	184.66 ±4.34[ab*]	189.09 ±3.65[a*]	185.11 ±3.45[a]
Stride Length Front (cm)	81.66 ±0.88[*]	82.78 ±0.74[*]	83.07 ±0.79[*]	83.31 ±0.67[*]
Stride Length Rear (cm)	81.40 ±0.88[*]	82.64 ±0.73[*]	82.79 ±0.79[*]	83.02 ±0.65[*]
Stride Duration Front (s)	0.51 ±0.01[a*]	0.48 ±0.01[ab*]	0.45 ±0.007[c]	0.46 ±0.007[bc]
Stride Duration Rear (s)	0.51 ±0.01[a*]	0.48 ±0.01[ab*]	0.45 ±0.007[c]	0.46 ±0.007[bc]
Swing Time Front (s)	0.23 ±0.002[a]	0.23 ±0.002[a]	0.22 ±0.002[b*]	0.22 ±0.002[b*]
Swing Time Rear (s)	0.26 ±0.003 [a]	0.25 ±0.003[a]	0.24 ±0.002[b]	0.25 ±0.002[b*]
Stance Time Front (s)	0.28 ±0.01[a*]	0.25 ±0.01[ab*]	0.23 ±0.006[c*]	0.25 ±0.006[bc*]
Stance Time Rear (s)	0.25 ±0.01[a*]	0.23 ±0.009[ab*]	0.20 ±0.006[c*]	0.23 ±0.005[bc*]
Percent Stance Front (%)	52.81 ±0.67[a*]	50.91 ±0.61[b*]	51.03 ±0.49[b*]	52.60 ±0.46[a*]
Percent Stance Rear (%)	47.32 ±0.69[a*]	45.31 ±0.60[b*]	44.79 ±0.50[b*]	46.07 ±0.48[ab*]

Within a row, the values with different superscripted significantly different (P < 0.05). Values are reported as mean ± SEM.

Asterisks denote differences of P < 0.05 for the value between the genders.

Table 5.4- Sire by day for study 1 EB 5 sired pigs

Measurements	D1 EB5	D2 EB5	D4 EB5	D8 EB5
Total Time on mat (min)	7.83 ±1.09^{a}	6.90 ±0.95^{ab}	5.36 ±0.78^{b}	4.98 ±0.92^{b}
Time to First Usable Run (min)	2.3968 ±0.62^{a}	1.30 ±0.34^{ab}	0.98 ±0.63^{b}	1.84 ±0.35^{ab}
Total Runs	15.52 ±1.30	17.32 ±1.46	15.17 ±1.53	15.67 ±1.57
Velocity (cm/s)	180.17 ±4.80^{b}	180.44 ±4.28^{b*}	184.02 ±3.44^{a}	204.8 ±3.40^{b}
Stride Length Front (cm)	83.76 ±0.85	82.75 ±0.73*	84.47 ±0.74	84.08 ±0.66
Stride Length Rear (cm)	83.60 ±0.85	82.59 ±0.72*	84.30 ±0.74	83.88 ±0.64
Stride Duration Front (s)	0.50 ±0.01^{a}	0.48 ±0.01^{ab*}	0.43 ±0.007^{c}	0.46 ±0.007^{b}
Stride Duration Rear (s)	0.50 ±0.01^{a}	0.48 ±0.01^{ab*}	0.43 ±0.007^{c}	0.46 ±0.007^{b}
Swing Time Front (s)	0.24 ±0.002^{a}	0.23 ±0.002^{b}	0.22 ±0.002^{c}	0.22 ±0.002^{c}
Swing Time Rear (s)	0.27 ±0.003^{a*}	0.26 ±0.003^{ab}	0.25 ±0.002^{b}	0.25 ±0.002^{b*}
Stance Time Front (s)	0.27 ±0.01^{a}	0.25 ±0.009^{ab}	0.22 ±0.006^{c}	0.24 ±0.006^{bc}
Stance Time Rear (s)	0.24 ±0.009^{a}	0.22 ±0.009^{ab*}	0.18 ±0.006^{c*}	0.20 ±0.005^{bc}
Percent Stance Front (%)	51.23 ±0.65^{a}	50.58 ±0.60^{ab*}	49.30 ±0.46^{b}	51.47 ±0.46^{a}
Percent Stance Rear (%)	45.19 ±0.67^{a}	43.78 ±0.59^{a}	41.97 ±0.47^{b*}	43.67 ±0.48^{a*}

Within a row, the values with different superscripted significantly different (P < 0.05). Values are reported as mean ± SEM.

Asterisks denote differences of P < 0.05 for the value between the sire lines.

Table 5.5- Sire by day for study 1 EB X sired pigs

Measurements	D1 EB X	D2 EB X	D4 EB X	D8 EB X
Total Time on mat (min)	7.03 ±1.12	5.46 ±0.98	4.88 ±0.80	6.72 ±0.94
Time to First Usable Run (min)	2.01 ±0.38	2.00 ±0.53	1.38 ±0.39	1.62 ±0.55
Total Runs	17.44 ±1.34	16.75 ±1.50	16.01 ±1.57	18.69 ±1.61
Velocity (cm/s)	198.85 ±4.67^{c}	194.78 ±4.46^{a*}	187.96 ±3.50^{ab}	189.38 ±3.29^{bc}
Stride Length Front (cm)	83.22 ±0.82^{b}	86.79 ±0.76^{a*}	84.71 ±0.75^{ab}	84.40 ±0.64^{a}
Stride Length Rear (cm)	82.97 ±0.83^{b}	86.55 ±0.75^{a*}	84.43 ±0.75^{b}	84.13 ±0.62^{b}
Stride Duration Front (s)	0.48 ±0.01^{a}	0.44 ±0.01^{b*}	0.44 ±0.007^{b}	0.45 ±0.007^{ab}
Stride Duration Rear (s)	0.48 ±0.01^{a}	0.44 ±0.01^{b*}	0.44 ±0.007^{b}	0.46 ±0.007^{ab*}
Swing Time Front (s)	0.23 ±0.002^{a}	0.22 ±0.002^{b}	0.22 ±0.002^{b}	0.22 ±0.002^{b}
Swing Time Rear (s)	0.25 ±0.003^{a*}	0.24 ±0.003^{b}	0.24 ±0.002^{b}	0.25 ±0.002^{ab*}
Stance Time Front (s)	0.25 ±0.01^{a}	0.21 ±0.01^{c}	0.22 ±0.006^{bc}	0.23 ±0.005^{ab}
Stance Time Rear (s)	0.22 ±0.009^{a}	0.19 ±0.009^{b*}	0.20 ±0.005^{b*}	0.21 ±0.005^{ab}
Percent Stance Front (%)	50.61 ±0.63^{ab}	47.70 ±0.62^{c*}	49.47 ±0.47^{b}	50.89 ±0.44^{a}
Percent Stance Rear (%)	46.18 ±0.65^{a}	43.00 ±0.62^{c}	44.25 ±0.48^{bc*}	45.10 ±0.46^{ab*}

Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Asterisks denote differences of $P < 0.05$ for the value between the sire lines.

Table 5.6- Gender by weight points for study 2 females

Measurements	F 23	F 45	F 68	F 91	F 113	F 136
Velocity (cm/s)	200.2±3.73^{ab*}	207.8±3.99^{a}	190.6±4.63^{bc}	193.7±4.34^{bc}	181.0±5.35^{c*}	183.2±4.02^{bc}
Stride Length Front (cm)	71.05±0.81^{e*}	81.14±0.80^{d}	83.87±1.03^{c}	87.15±0.84^{b*}	90.06±1.17^{a*}	92.50±0.76^{a}
Stride Length Rear (cm)	71.04±0.80^{d*}	81.07±0.79^{c}	83.47±1.01^{c}	86.74±0.85^{b}	89.68±1.16^{a*}	92.07±0.74^{a}
Cycle Time Front (s)	0.36±0.005^{d*}	0.40±0.007^{c}	0.46±0.01^{b*}	0.47±0.01^{b}	0.51±0.01^{a*}	0.52±0.01^{a}
Cycle Time Rear (s)	0.36±0.006^{d*}	0.40±0.007^{c}	0.46±0.01^{b*}	0.47±0.01^{b}	0.50±0.01^{a*}	0.52±0.01^{a}
Swing Time Front (s)	0.21±0.001^{d}	0.22±0.002^{c}	0.23±0.002^{b*}	0.23±0.002^{b}	0.24±0.003^{a}	0.23±0.003^{a}
Swing Time Rear (s)	0.23±0.002^{c}	0.24±0.002^{c}	0.25±0.003^{b*}	0.24±0.003^{b}	0.26±0.004^{a*}	0.25±0.003^{a*}
Stance Time Front (s)	0.15±0.005^{d*}	0.18±0.006^{c}	0.23±0.009^{b}	0.24±0.008^{b*}	0.27±0.01^{a}	0.29±0.009^{a}
Stance Time Rear (s)	0.12±0.004^{d*}	0.16±0.005^{c}	0.21±0.008^{b}	0.22±0.008^{b*}	0.25±0.01^{ab}	0.27±0.009^{a}
Percent Stance Front (%)	40.01±0.54^{e*}	44.35±0.53^{d}	49.33±0.66^{c}	50.43±0.56^{c*}	52.50±0.74^{b}	54.26±0.50^{a}
Percent Stance Rear (%)	34.89±0.48^{e*}	40.21±0.44^{d}	44.08±0.70^{c}	46.58±0.50^{b*}	48.21±0.73^{b}	50.37±0.55^{a}

Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Asterisks denote differences of $P < 0.05$ for the value between the genders.

Table 5.7- Gender by weight points for study 2 males

Measurements	M 23	M 45	M 68	M 91	M 113	M 136
Velocity (cm/s)	169.6 ±4.32^{bc*}	198.4 ±4.77^{a}	182.3 ±5.33^{b}	183.0 ±5.57^{b}	161.1 ±4.58^{c*}	178.7± 4.46^{bc}
Stride Length Front (cm)	64.30 ±0.93^{d*}	79.11 ±0.95^{c}	85.43 ±1.18^{b}	84.31 ±1.08^{b*}	86.34 ±1.00^{b*}	90.71 ±0.84^{a}
Stride Length Rear (cm)	64.28± 0.93^{d*}	78.85 ±0.95^{c}	85.41 ±1.17^{b}	84.13 ±1.09^{b}	86.02 ±1.00^{b*}	90.20 ±0.82^{a}
Cycle Time Front (s)	0.39 ±0.006^{d*}	0.41±0.008^{d}	0.49 ±0.01^{c*}	0.48 ±0.01^{c}	0.57 ±0.01^{a*}	0.52 ±0.01^{b}
Cycle Time Rear (s)	0.39 ±0.006^{d*}	0.41 ±0.008^{d}	0.49 ±0.01^{c*}	0.48 ±0.01^{c}	0.57 ±0.01^{a*}	0.53 ±0.01^{b}
Swing Time Front (s)	0.21 ±0.002^{d}	0.22 ±0.002^{c}	0.24 ±0.003^{b*}	0.22 ±0.003^{c}	0.24 ±0.003^{a}	0.23 ±0.003^{b}
Swing Time Rear (s)	0.23 ±0.002^{d}	0.24 ±0.003^{d}	0.27 ±0.003^{b*}	0.25 ±0.004^{c}	0.27 ±0.003^{a*}	0.26 ±0.003^{b*}
Stance Time Front (s)	0.18 ±0.006^{d*}	0.19 ±0.007^{d}	0.25 ±0.01^{c}	0.25 ±0.01^{c}	0.33 ±0.01^{a}	0.30 ±0.01^{b}
Stance Time Rear (s)	0.16 ±0.005^{d*}	0.17 ±0.006^{d}	0.22 ±0.01^{c}	0.23 ±0.01^{c*}	0.29 ±0.01^{a}	0.26 ±0.01^{b}
Percent Stance Front (%)	44.73 ±0.62^{d*}	45.74 ±0.64^{d}	50.00 ±0.76^{c}	52.11 ±0.72^{b*}	56.19 ±0.63^{a}	55.02 ±0.56^{a}
Percent Stance Rear (%)	39.39 ±0.55^{e*}	41.46 ±0.52^{d}	44.02 ±0.80^{c}	47.05 ±0.65^{b*}	51.00 ±0.63^{a}	49.19 ±0.63^{a}

Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Asterisks denote differences of $P < 0.05$ for the value between the genders.

Table 5.8- Sire by weight points for study 2 EB 5 sired pigs.

Measurements	23 EB 5	45 EB 5	68 EB 5	91 EB 5	113 EB 5	136 EB 5
Velocity (cm/s)	183.49 ±3.63^{b}	199.21 ±4.14^{a}	181.23±4.59^{bc}	180.3±4.59^{bc*}	173.64±4.17^{bc}	171.46±3.92^{c*}
Stride Length Front (cm)	65.42 ±0.78^{b*}	78.12 ±0.82^{c*}	82.69±1.02^{b*}	81.62±0.89^{b*}	86.49±0.91^{a*}	88.49±0.74^{a*}
Stride Length Rear (cm)	65.42 ±0.78^{d*}	78.04±0.82^{c*}	82.46±1.01^{b*}	81.46±0.90^{b*}	86.15±0.91^{a*}	88.14±0.72^{a*}
Cycle Time Front (s)	0.36 ±0.005^{d*}	0.40±0.007^{c}	0.47±0.01^{b}	0.46±0.01^{b}	0.51±0.01^{a*}	0.54±0.01^{a}
Cycle Time Rear (s)	0.36 ±0.005^{d*}	0.40±0.007^{c}	0.47±0.01^{b}	0.46±0.01^{b}	0.51±0.01^{a*}	0.54±0.01^{a*}
Swing Time Front (s)	0.21 ±0.001^{c*}	0.22±0.002^{b*}	0.23±0.002^{a}	0.22±0.002^{b*}	0.23±0.002^{a*}	0.23±0.003^{a}
Swing Time Rear (s)	0.23 ±0.002^{c*}	0.23±0.002^{c*}	0.25±0.003^{a*}	0.24±0.003^{b*}	0.25±0.003^{a*}	0.25±0.003^{a}
Stance Time Front (s)	0.15 ±0.005^{e*}	0.18±0.006^{d}	0.24±0.009^{c}	0.24±0.009^{c}	0.28±0.01^{b}	0.31±0.009^{a*}
Stance Time Rear (s)	0.14 ±0.004^{e*}	0.17±0.005^{d}	0.22±0.008^{c}	0.23±0.008^{c}	0.26±0.009^{b}	0.29±0.009^{a*}
Percent Stance Front (%)	41.79 ±0.52^{f}	45.14±0.65^{e}	50.21±0.65^{d}	52.04±0.60^{c}	54.60±0.57^{b}	56.21±0.49^{a*}
Percent Stance Rear (%)	37.28 ±0.47^{f}	41.82±0.69^{e*}	45.52±0.69^{d*}	48.31±0.53^{c*}	50.21±0.57^{b}	51.85±0.54^{a*}

Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Asterisks denote differences of $P < 0.05$ for the value between the sire lines.

Table 5.9- Sire by weight points for study 2 EB X sired pigs

Measurements	23 EB X	45 EB X	68 EB X	91 EB X	113 EB X	136 EB X
Velocity (cm/s)	186.29±4.40^{b}	206.93±4.65^{a}	191.67±5.37^{b}	196.41±5.37^{ab*}	168.48±5.67^{c}	190.3±4.55^{b*}
Stride Length Front (cm)	69.92±0.95^{d*}	82.14±0.93^{c*}	86.61±1.19^{b*}	89.85±1.04^{b*}	89.91±1.24^{b*}	94.71±0.86^{a*}
Stride Length Rear (cm)	69.89±0.95^{d*}	81.88±0.92^{c*}	86.43±1.18^{b*}	89.42±1.05^{b*}	89.55±1.23^{b*}	94.14±0.84^{a*}
Cycle Time Front (s)	0.39±0.006^{e*}	0.41±0.008^{d}	0.47±0.01^{c}	0.48±0.01^{bc}	0.5605±0.02^{a*}	0.51±0.01^{b}
Cycle Time Rear (s)	0.39±0.007^{c*}	0.41±0.008^{c}	0.47±0.01^{b}	0.48±0.01^{b}	0.56±0.02^{a*}	0.51±0.01^{b*}
Swing Time Front (s)	0.22±0.002^{c*}	0.22±0.002^{c*}	0.24±0.003^{b}	0.23±0.003^{b*}	0.24±0.003^{a*}	0.24±0.003^{b}
Swing Time Rear (s)	0.24±0.002^{c*}	0.24±0.003^{c*}	0.27±0.003^{b*}	0.26±0.004^{b*}	0.28±0.004^{a*}	0.27±0.003^{b}
Stance Time Front (s)	0.17±0.006^{d*}	0.19±0.006^{d}	0.24±0.01^{c}	0.25±0.01^{bc}	0.31±0.01^{a}	0.27±0.01^{b*}
Stance Time Rear (s)	0.15±0.005^{d}	0.17±0.006^{c*}	0.21±0.01^{b}	0.22±0.009^{b}	0.28±0.01^{a}	0.25±0.01^{ab*}
Percent Stance Front (%)	42.96±0.63^{e}	44.94±0.62^{d}	49.12±0.76^{c}	50.49±0.70^{b}	54.08±0.78^{a}	53.07±0.57^{a*}
Percent Stance Rear (%)	37.01±0.56^{e}	39.85±0.51^{d*}	42.58±0.81^{c*}	45.32±0.62^{b*}	48.53±0.78^{a}	47.71±0.62^{a*}

Within a row, the values with different superscripted significantly different ($P < 0.05$). Values are reported as mean ± SEM.

Asterisks denote differences of $P < 0.05$ for the value between the sire lines.

CHAPTER 6

The effect of blunt trimming versus functional trimming on sows

Introduction

Lameness is a major issue in the swine industry. Lameness can be caused by several factors, ranging from limb malformation to infected skin lesions (Cador et al., 2014; Traulsen et al., 2016). Within a sow herd, 9 percent of removals are due to lameness or foot lesions (Traulsen et al., 2016). Gestation crates reduce cardiovascular fitness, muscle weight, and bone strength, and increased morbidity and unresolved aggression in sows (Harris et al., 2006). Despite the draw-backs, sows housed in gestation crates have a lower prevalence of lameness compared to those in group housing pens (Cador et al., 2014).

Functional trimming is the correction of claw horn overgrowth and reestablishing even weight distribution across the limb. The functional trimming method comes from a cattle trimming technique of five steps originally developed in the Netherlands by (Toussaint et al., 1985); sometimes referred as the Dutch trimming method. Claw trimming within the swine industry is not a standard practice as it is in dairy cows. Results from past sow studies revealed no improvement in longevity, nor any clear effect on claw lesion development, thus not supporting additional labor and costs associated with regular, preventive claw trimming (reviewed by (Pluym et al., 2013). Yet, with increasing herd lameness, the adjustment to group housing, and improvement of claw trimming techniques, claw trimming may warrant further evaluation.

Blunt trimming just takes length off of the claw by cutting the toe off without balancing any other part of the claw. This method is fast and cheaper due to being able to trim the toe off while the pig is in a crate or lying down, therefore no chutes or special equipment is needed. This method also does not require the training that is necessary for functional trimming. This allows for anyone on staff to be able to trim the animal with minimum risk of injury to the pig or the handler. The down side to blunt trimming is that there is no change in height or angle of the claw, which can lead to further issues. One of the issue is that leaving the toe square instead of rounding it off increases the chance of the sow stumping its toe as it walks and creating more damage to the hoof.

Computer assisted gait analysis is a widely accepted tool that is more accurate in assessing gait deviation than visual gait analysis (Wren et al., 2011). Such analysis can be used to assess changes to the sow's gait in response to claw trimming. Gait analysis can be used to detect abnormalities in swine that are not visually observable (Stavrakakis et al., 2014). Gait analysis programs illustrate the differences in gait characteristics of lame sows (Mohling et al., 2014). This helps to provide a basis on which to compare subclinical gait changes, in response to lameness or treatment.

The objective of this study was to see the effect of functional claw trimming verses blunt trimming on the gait of sows. Our hypothesis was that blunt trimming will not improve the gait of the sow, due to not addressing all the issues that are related to having long claws and that functional trimming of long claws and dewclaws would positively alter the sow's gait, due to increased freedom of movement.

Materials and Methods

Experimental protocols were approved by the University of Georgia (Athens, Ga) Institutional Animal Care and Use Committee (AUP#A2016 01-010-R2). In this study, 19 PIC C29 (Pig Improvement Corporation, Franklin, KY, USA) bred sows from the University of Georgia research herd were used. Sows were multiparous and were all open. None of the sows that were used were visually lame and sows had a body condition score of 2.5-3.5 out of 5. All of the sows had overgrowth of the claws and were used to the handling. Due to the short time frame of this study, none of the sows were trained to walk on the track. Sows were recorded immediately pre-dewclaw trimming, pre-blunt trimming, pre-functional trimming, and 4 days post-functional trimming. All sows were used as their own control and were compared back to their original gait.

Sows were walked through a commercial hog panel walled dog bone track with a 7.5-meter-long GAITRite gait collection mat (GAITRite, Franklin, New Jersey). Sows were walked through the gait track until 6 usable repetitions were recorded or a maximum of 20 minutes had passed. Following pre-trimming videography, sows were moved to another room for trimming. Sows were given three days to adjust to each of the trimmings in individual pens, with adequate feed and water provided. Each day repeated this process.

Functional Claw Trimming

Following recording, sows were loaded into a Feet First® (Zinpro Corporation, Eden Prairie, MN, USA) chute, equipped with a padded center support, allowing for ventral cushioning of the sow. The front and rear chute gates were secured, and the chute was raised to allow trimmers easy access to the claws. Hobbles with Velcro were tightly fastened around the pasterns of the front limbs as needed. Most sows did not require additional restraint and remained calm in the chute.

On D1, sows had all 8 of their dewclaws trimmed even with the coronary band, so that they would not interfere with trimming results using tree pruners. On D4, sow's had the claws blunt trimmed using tree pruners to 6.5 cm from the coronary band. Claws were closely trimmed straight across the line drawn on the claw. The bottom of the foot was not leveled and the side walls were not corrected. On D8, claws were correctively trimmed using DeWalt heavy-duty 11.5 cm (model D28402W, Baltimore, MD, USA) power grinders with 20.34 cm, 60 grain grinding pads. Each claw was marked following Zinpro's Feet First®: Functional Sow Claw Trimming protocol at 5.5 cm from the coronary bands, with dewclaws marked even with the coronary band. Claws were then carefully shaped, so that each claw would not interfere with its partner, and would maintain a rounded edge, decreasing bluntness and providing a smooth, level sole. Each claw was carefully inspected visually and tacitly for evenness to ensure that pressure applied to the foot would be distributed evenly across both claws and heel.

Recorded Analysis

Recordings from the mat were collected in the GAIT4Dog software program (GAITRite, Franklin, New Jersey). This program provides a digital copy of the pig's footfalls as the land on the mat. The footfalls are then processed so that each one is numbered in the order they land. Once all feet are assigned a number, the program designates the foot that the footfall belongs to depending on direction of travel and pattern of movement so that each foot is categorized as right front, left front, right rear or left rear. Any erroneous assignments of number or foot assignment can be corrected by the user before the run is analyzed for gait parameters. Velocity, stance time, swing time, stride duration, stride length, foot and percent stance of stride duration were measured for each video. Measurements were compared over time.

Data Analysis

Data were analyzed in SAS (version 9.4; SAS Institute Inc., Cary, NC, USA) using a PROC MIXED procedure to evaluate the differences of the two paired limbs at the four time points as repeated measures. Time in seconds and distance in centimeters were the dependent variables of interest. Statistical significance was considered at $P < 0.05$ for all parameters measured, and PDIFF was used to separate means where necessary.

Results and Discussion

When looking at the results, there was an improvement in gait and movement across the mat due to trimming dewclaws up to the coronary band. This is seen in the increase in velocity ($P < 0.03$; Figure 6.1A), increase stride length ($P < 0.02$; Figure 6.1B), decrease in stride duration ($P < 0.04$; Figure 6.1C), decrease in stance ($P < 0.04$; Figure 6.1D) and decrease in rear percent stance ($P < 0.03$; Figure 6.1F) from D1 to D4. There was a slight change in swing that was not significant, which may be an effect of shortening the dewclaws. By decreasing the length of the dewclaws, the heel is able to make contact with the floor faster because the dewclaws are not interfering with the heel contact.

Blunt trimming was shown to not improve gait of the sows. The only significant changes that were seen were rear percent stance ($P < 0.02$; Figure 6.1F) from D1 to D8 and front swing ($P < 0.04$; Figure 6.1E) from D4 to D8. This shows that there is a larger benefit from trimming dewclaws compared to blunt trimming the toe of the claw. The lack of benefit mostly likely is due to the trimming only taking care of the length of the claw, while ignoring height of claw and any abnormalities to the wall shape of the claw. By ignoring these issues, blunt trimming is not balancing the hoof so that it resembles the natural shape of the hoof. Blunt trimming also leaves the hoof with a square toe, which increases the chances of the sows to stub their claw toes and cause more damage to their claw than if the claw was rounded.

Function claw trimming shows the greatest improvement compared to the other trimming methods. When looking from D1 to D12, the sows moved forward more efficiently, which is seen in the smaller stance ($P < 0.0001$, Figure 6.1D), percent stance ($P < 0.0001$; Figure 6.1F) and stride duration ($P < 0.003$; Figure 6.1C). Stride length ($P < 0.008$; 6.1B) and velocity ($P < 0.003$; Figure 6.1A) increased, showing that the sows were move comfortable moving across the mat on D12 compared to the shorter, slower strides that they had on D1. Swing did not change, showing that the improvement in stride duration value was only due to the pigs being more comfortable having their feet off the ground.

When comparing the functional trimming to dewclaw trimming we can see that the benefits trimming dewclaws provides relief that is close to that seen when correctively trimming dewclaws. The only measurements that was significantly different between D4 to D12 was front swing ($P< 0.03$; Figure 6.1E) and percent stance ($P < 0.0001$; Figure

6.1F). These two measurements show that functional trimming had a higher benefit to the pigs than the dewclaw trimming as the sows were more willing to move their limbs through the air instead of having them on the ground during the stride duration.

When looking at blunt trimming verses functional trimming, it is clear that functional trimming improves the gait of the sows. Pigs were more efficient when moving across the mat after functional trimming as is seen in the decrease in stance ($P < 0.005$; Figure 6.1D), stride duration ($P < 0.03$; Figure 6.1C) and percent stance ($P < 0.02$; Figure 6.1F). The increase in stride length ($P < 0.04$; Figure 6.1B) and velocity ($P < 0.009$; Figure 6.1A), in conjunction to the decrease in the before mentioned values, shows that the pigs stood during stride duration less and that they moved across a greater distance in a shorter amount of time. This means that these pigs would move from point A to point B not only easier, but in a quicker amount of time.

Conclusion

Trimming is an important method to help prevent and treat lameness. In this study, functional trimming was shown to be the best method of trimming due to its improvement to gait parameters. If the farm is unable to correctively trim their sows, trimming dewclaws has a larger benefit than blunt trimming the claws. Overall, blunt trimming was shown to have little to no benefits in gait parameters, therefore is not recommended to be used. Future studies are needed to look at the long term effects of blunt trimming verses correctively trimming or trimming dewclaws only. This study also should be repeated with more sows to improve its impact.

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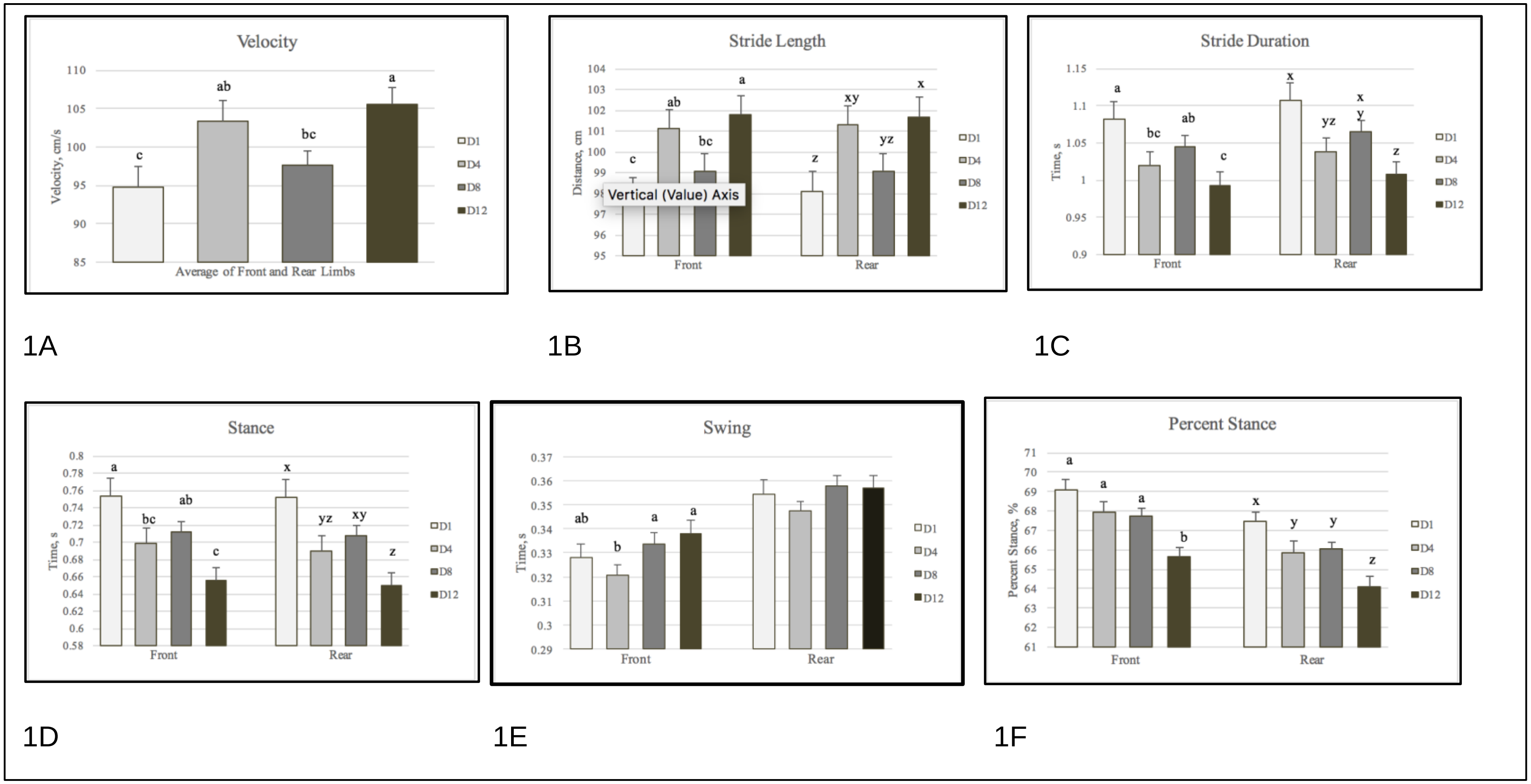
Figure 6.1- Measurements across the days for front and rear limbs



P < 0.05 is represented by the different letters. A: Average velocity for the days. B: Stride length across the days. C: Stride duration across the days. D: Stance time across the days. E: Swing time across the days. F: Percent stance across the days.

CHAPTER 7

EFFECTS OF FEEDING A MINERAL AMINO ACID COMPLEX FROM NURSERY TO SECOND PARITY ON SOW PRODUCTIVITY AND GAIT ANALYSIS

Introduction

Lameness is a growing issue within the swine industry due to the move to group housing in the sow barns. Lameness is a major factor for welfare because of high prevalence and debilitating effects (Bicalho and Oikonomou, 2013). Lameness has been shown to be higher in group-housed sows than their individual-stalled counterparts, primarily due to aggressive interactions and increased mobility (Anil et al., 2003; Anil et al., 2009; Traulsen et al., 2016). The lame sow is expected to have a reduction in activity level, social and explorative behavior, and feeding behavior (Heinonen et al., 2013). This activity change challenges the five freedoms of the sow (Heinonen et al., 2013).

It has been shown that sows that are lame have significantly lower daily water intake than sound sows (Heinonen et al., 2013). This decrease causes a drop in the reproduction efficacy of the sow, which is unable to compete with healthy-legged sows for food and water (Heinonen et al., 2013). Because of the negative impact on productivity, lameness is one of the major welfare indicators of the herd (Bicalho and Oikonomou, 2013; Cador et al., 2014; Lisgara et al., 2015). Reduction of longevity and number of piglets born every year can be traced back to the increased culling rates due to lameness (Lisgara et al., 2015). Sows that are lame are removed at an earlier age than those culled for other reasons, which leads to removal before the maximum productivity is reached (Anil et al., 2005). This leads to a smaller average litter size for the herd, which negatively impacts the efficiency of production.

Nutrition is a vital part of the production facility as it is the biggest cost and has the largest effect when producing pigs. Malnutrition leads to impaired horn production, especially when there is insufficiency of amino acids, vitamins or minerals (van Riet et al., 2016). Both feed and water intake of the sow are correlated to the weaning weight of the piglets (Kruse et al., 2011). The intake of both feed and water have been shown to be negatively impacted by lameness, and therefore the weight of the weaned piglets are negatively impacted as well. Claw makeup is based on nutrients that include fatty acids, the amino acids cysteine and methionine, the minerals calcium, zinc, copper, selenium, manganese and chromium and vitamin A, D, E and biotin (Pluym et al., 2013). These nutrients are provided to the sow through her diet, yet may be in deficit during lactation when the sow's nutrient needs are extremely high.

When looking at nutrition, it is important to consider the microminerals within the diet. Trace mineral intake and storage is a vital issue to consider because these minerals are required for metabolic function, such as immune response, antioxidant properties, energy metabolism, and other physiological functions (Liu et al., 2016; Lopes et al., 2017). Microminerals, such as zinc and manganese, are important because they are needed for vital biochemical mechanisms needed for animal growth and development (Lopes et al., 2017). Organic minerals are absorbed by intestinal carriers of amino-acids and peptides, unlike inorganic minerals that are transported by intestinal transporters, which prevents minerals from competing for absorption through the using the same absorption mechanisms (Lopes et al., 2017). The change in absorption improves not only bioavailability, but also improves movement of minerals to tissues and retention within those tissues (Liu et al., 2014; Liu et al., 2016; Lopes et al., 2017). However, organic minerals are traditionally more expensive when compared to inorganic minerals, even when the larger inclusion rate of inorganic minerals in the diet is taken into consideration (Lopes et al., 2017). It has also been shown that pigs that received the same level of organic minerals as the pigs that received inorganic minerals had lower levels of zinc, manganese, and copper in the fecal material, showing that the minerals were retained at a higher level (Creech et al., 2004; Lebel et al., 2014; Liu et al., 2014; Liu et al., 2016). Decreasing the copper and zinc in manure allows for more manure to be able to be spread without causing toxicity within plants (Creech et al., 2004). For this study, gilts were taken at weaning and fed a basal diet or a basal diet with the addition of an amino acid mineral complex. Both groups were followed through their second parity to track changes that occur over time.

Materials and Methods

Experimental protocols were approved by the University of Georgia (Athens, Ga) Institutional Animal Care and Use Committee (AUP#A2016 01-010-R2). In this study, 70 Choice Genetics (CG 32) gilts were randomly assigned to one of two treatments at weaning. The first group were the control gilts, who received the standard diets provided to the University of Georgia's swine herd. This diet met NRC values for all phases of nursery, grower, gestation and lactation (Table 11 and Table 12). Diets were fed according to the pig's weight, age and phase of life. Nursery was fed from weaning until around pigs reached around 23 kg in three, two week phases. Grower was fed from 23 kg until gilts were bred. At breeding, sows were fed the gestational diet until farrowing. During lactation, sows were fed the lactation diet until piglets were weaned. The second group received 750 g/ metric ton of Availa-Sow® (50 ppm Zn, 20 ppm Mn, 10 ppm Cu) in addition to the control diet. Both groups remained on their respective diet until after they weaned their second litter. Performance data was collected for number of pigs born, birth weight, number of pigs weaned, and weaning weight. Midway through gestation for the first and second parity, the sows were brought in for gait data collection and claw and dewclaw length measurements.

For gait data collection, pigs were walked back and forth through a dog bone track made of commercial hog panels and across the 7.5 m GAITRite® pressure mat (GAITRite, Franklin, New Jersey). Pigs were brought into the gait room from their pens one at a time. At each time point, the pigs were trotted across the pressure mat until 6 usable reps were obtained or a maximum of 20 minutes had passed from the start of the session. Data were analyzed by the GAIT4Dogs® gait analysis program.

Following recording, sows were loaded into a Feet First® (Zinpro Corporation, Eden Prairie, MN, USA) chute, equipped with a padded center support, allowing for ventral cushioning of the sow. The front and rear chute gates were secured, and the chute was raised to allow access to claws. Hobbles with Velcro were tightly fastened around the pasterns of the front limbs as needed. Most sows did not require additional restraint and remained calm in the chute. While in the chute, claws and dewclaws were measured starting from the edge of the coronary band down the middle of the claw to the toe. After all of the pig's claws and dewclaws were measured, pigs were returned to their pens where they have free choice of feed and water.

Recorded Analysis

Recordings from the mat were collected in the GAIT4Dog® software program (GAITRite, Franklin, New Jersey). This program provides a digital copy of the pig's footfalls as the land on the mat. The footfalls are then processed so that each one is numbered in the order they land. Once all feet are assigned a number, the program designates the foot that the footfall belongs to depending on direction of travel and pattern of movement so that each foot is categorized as right front, left front, right rear or left rear. Any erroneous assignments of number or foot assignment can be corrected by the user before the run is analyzed for gait parameters. Velocity, stance, swing, stride duration, stride length, total pressure index, rear reach and percent stance of stride duration were measured for each video. Measurements were compared over time.

Statistics

Data were analyzed in SAS (version 9.4; SAS Institute Inc., Cary, NC, USA) using a PROC MIXED procedure to evaluate the differences of the two paired limbs at the two time points as repeated measures. Time in seconds, distance in centimeters and weight in kg were the dependent variables of interest. Statistical significance was considered at $P < 0.05$ for all parameters measured, and PDIFF was used to separate means where necessary.

Results

Birth weight, number of piglets born, weaning weight, and number of piglets weaned were not significantly different between treatments for either parity. Claws increased from first parity to second parity ($P < 0.0001$; Table 13), but there was no significant difference between treatment and control. Rear dewclaws increased from first parity to second parity ($P < 0.01$, Table 13). All other dewclaw comparisons were not significant.

Velocity was higher for treatment sows compared to control sows for the second parity ($P < 0.03$; Figure 2A). Stride length increased from first parity to second parity for both treatment and control sows ($P < 0.0001$; Figure 2B), but the two groups were not significantly different from each other. Stride duration and its components of swing and stance increased for control animals from first parity to second parity ($P < 0.04$; Figure 3A, Figure 3B, and Figure 3C) for both front and rear limbs. There was no significant change in stride duration, swing, or stance for treatment sows, but treatment sows did have significantly shorter stride duration, swing and stance compared to control sows during the second parity ($P < 0.007$; Figure 3A, Figure 3B, and Figure 3C).

Front percent stance was significantly lower for treatment sows during second parity compared to control sows ($P < 0.04$, Figure 3D). Front total pressure index increased for control sows ($P < 0.005$, Figure 3E) and decreased for treatment sows ($P < 0.04$, Figure 3E) from first to secondary parity. Rear total pressure index decreased for control sows ($P < 0.005$, Figure 3E) and increased for treatment sows ($P < 0.04$; Figure 3E). For front total pressure index, first parity treatment sows had higher values compared to controls ($P < 0.01$; Figure 3E) and in second parity treatment sows were significantly lower than controls (P < 0.02; Figure 3E). Rear total pressure index was significantly lower for treatment sows compared to control sows for first parity (P < 0.01; Figure 3E) and were significantly higher for second parity (P < 0.02, Figure 3E).

Discussion

Performance data showed no differences between treatments or parity. While there were no significant differences, there was a numerical increase for piglets born and weaned for both treatments from first to second parity. This increase is to be expected as number of piglets born is known to increase as the sow ages, this in turns increases the number of piglets that have a chance of being weaned. There was a trend with the claw lengths increasing across the parities, but there were no significant differences between the two treatments. This shows that the claws are growing faster than they are being worn down. The continual excess growth will need to be trimmed as overgrowth is a type of claw lesion and claw lesions have been shown to be a major cause of lameness in sows (Calderón Díaz et al., 2014). Rear dewclaw lengths were significantly longer for controls during their second parity compared to their first parity. This shows that dewclaws were no longer wearing due to friction with the floor and leading to overgrowth.

The changes that were seen in this study for treatment sows in their second parity could be a reflection of their self-selected velocity. This higher velocity within the second parity treatment sows shortened the stride duration, swing and stance times overall. The quality of the gait is higher in the second parity sows due to their smaller percent stance and longer stride length. These measurements show that the treatment sows were covering the same distance in a shorter time by spending more time with their limbs in the air moving forward. Having limbs in the air for longer is an illustration of the comfort of the sow as they are willing to bear more weight across less limbs for extended periods of time.

For control sows, an increase in stride duration, swing and stance from first parity to second parity illustrates a degradation in gait quality from first parity to the second parity. In lame sows, there is a tendency of shorter stride lengths, lower velocity, and longer stance times than sound sows (Abell et al., 2014). The shift in weight between front and rear limbs that is seen in total pressure index may not be biologically significant even though it is statistically significant. The differences between both first and second parity and treatment and control are less that a percentage point different, which still falls into the range of expected values. Sows carry 54% of their weight on their forelimbs (Thorup et al., 2007). The distribution of weight is seen in quadrupeds because their center of mass is located around their shoulder area. The higher load and impacts on the forelimbs due to weight distribution causes leg problems at a higher frequency in fore rather than rear legs (Thorup et al., 2007). This difference in weight distribution also leads to differences in gait biomechanics when comparing the rear legs to the front.

Conclusion

The mineral amino acid-complex had beneficial effects on gait by the second parity. While there were trends within the data, the effects seen in gait analysis were not seen in the production or claw length data. While the mineral amino acid-complex cannot be said to have prevented lameness from occurring, the small differences that were seen in the control animals could be the forewarning of future issues. Further studies are needed to follow sows through their third or fourth parity, in which they reach their full production potential, to see if the early trends that were denoted continue or if a larger pattern emerges

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Table 7.1-Control diet for nursery and grower phases

	Nursery			Grow-Finish	
Phase	I	II	III	G-1	G-2
Age, weeks	3-4	4-6	6-8	8-12	12-16
Body weight, lb	10-15	15-25	25-55	55-110	110-170
Corn	40.56	49.71	64.06	60.43	60.65
DDGS	-	-	-	20.00	20.00
Whey	27.5	10.00	-	-	-
Soybean meal	16.78	31.55	30.82	14.41	15.76
Spray Dried Plasma Protein	5.0	-	-	-	-
Fat	1.65	2.26	1.35	2.34	1.00
Fish Meal	5.0	3.0	-	-	-
Dicalcium Phosphate	0.17	0.76	1.57	0.31	0.06
Limestone	0.88	0.87	0.84	1.11	1.60
Salt	0.20	0.25	0.35	0.35	0.35
Zinc Oxide	0.375	0.25	-	-	-
Vitamin premix	0.25	0.25	0.25	0.15	0.15
Mineral. Premix	0.15	0.15	0.15	0.15	0.15
Methionine	0.18	0.14	0.13	-	-
Lysine	0.30	0.30	0.40	0.40	0.29
Threonine	-	0.02	0.07	-	-
Antibiotic	1.00	0.50	-	-	-
Phytase	-	-	-	0.012	0.025
Calculated Analysis					
Energy, ME kcal/kg	3400	3400	3350	3400	3400
Crude Protein, %	22.18	21.74	20.71	16.3	13.6
Total Lysine, %	1.65	1.53	1.40	1.00	0.80
SID Lysine, %	1.50	1.35	1.23		
Calcium, %	0.85	0.80	0.75	0.75	0.70
Phosphorus, total %	0.65	0.58	0.41	0.65	0.60
Available, %	0.45	0.41	0.35	0.39	0.36

Note that the mineral premix is made of inorganic minerals. Treatment diets only differed in the addition of the amino acid mineral complex of 50 ppm Zn, 20 ppm Mn and 10 ppm Cu.

Table 7.2- Control diet for gestation and lactation

	Gestation Diet	Lactation Diet
Corn	53.54	38.96
SBM	3.23	17.23
DDGS	40.00	40.00
Poultry Fat	-	0.46
Dical	0.28	-
Limestone	1.74	2.16
Salt	0.35	0.35
Vitamins	0.25	0.25
Trace Minerals	0.15	0.15
Sow Pack	0.25	0.25
Lysine	0.21	0.20
Calculated Analysis		
Crude Protein	17.4	22.4
Metabolizable Energy,kcal/kg	3330	3300
Crude Fiber, %	4.18	5.10
Ether Extract, %	6.23	6.14
Lysine, %	0.70	1.10
TSAA, %	0.68	0.86
Threonine, %	0.64	0.92
Tryptophan, %	0.15	0.25
Ca, %	0.79	0.90
Total P, %	0.52	0.57
Available P, %	0.29	0.40

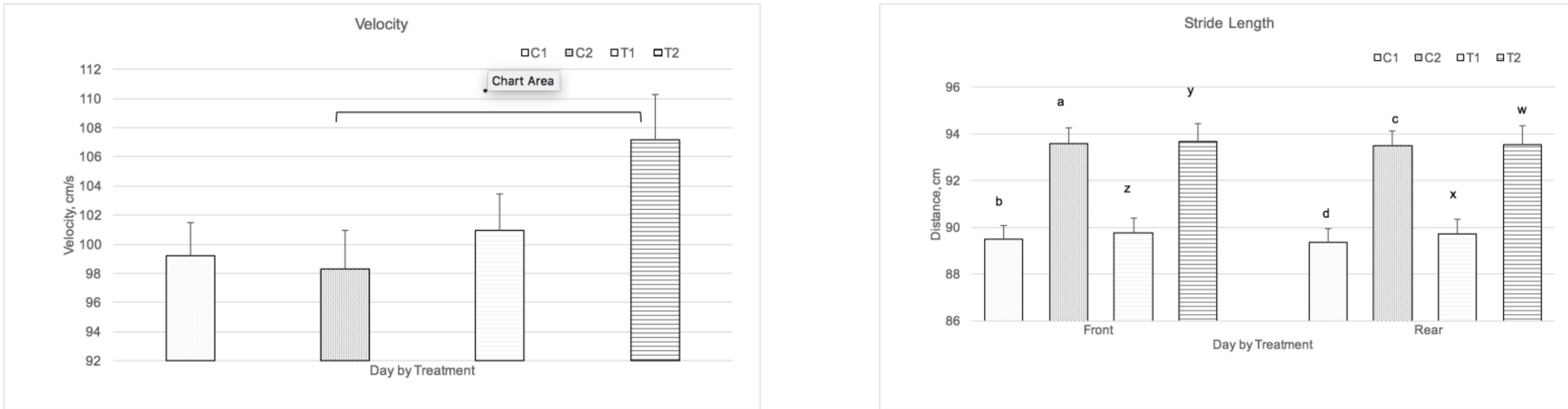
Note that the mineral premix is made of inorganic minerals. Treatment diets only differed in the addition of the amino acid mineral complex of 50 ppm Zn, 20 ppm Mn and 10 ppm Cu.

Table 7.3- Production, claw and dewclaw length values for both parities for treatment and control sows

	Control P1	Control P2	Treatment P1	Treatment P2
Number Born	9.6 ±0.54	11.0 ±0.53	9.8 ±0.64	10.9 ±0.66
Birth weight (kg)	1.79 ±0.14	1.79 ±0.17	1.69 ±0.17	1.76 ±0.21
Number Weaned	9.2 ±0.42	9.7 ±0.41	8.6 ±0.51	9.9 ±0.51
Weaning Weight (kg)	5.37 ±0.49	5.39 ±0.62	5.08 ±0.58	5.47 ±0.76
Front Claw Length (cm)	4.67 ±0.10	5.49 ±0.11	4.63 ±0.10	5.35 ±0.13
Rear Claw Length (cm)	4.61 ±0.09	5.36 ±0.13	4.63 ±0.11	5.39 ±0.16
Front Dewclaw Length (cm)	4.22 ±0.28	4.79 ±0.11	4.58 ±0.29	4.62 ±0.13
Rear Dewclaw Length (cm)	4.07 ±0.28	4.85 ±0.13	4.69 ±0.29	4.62 ±0.15

There were no significant differences between the values for number born, birth weight, number weaned or weaning weight. There were no significant differences between claw and dewclaw lengths between the two treatments. $P < 0.05$ between first parity to second parity for control and treatment animals.

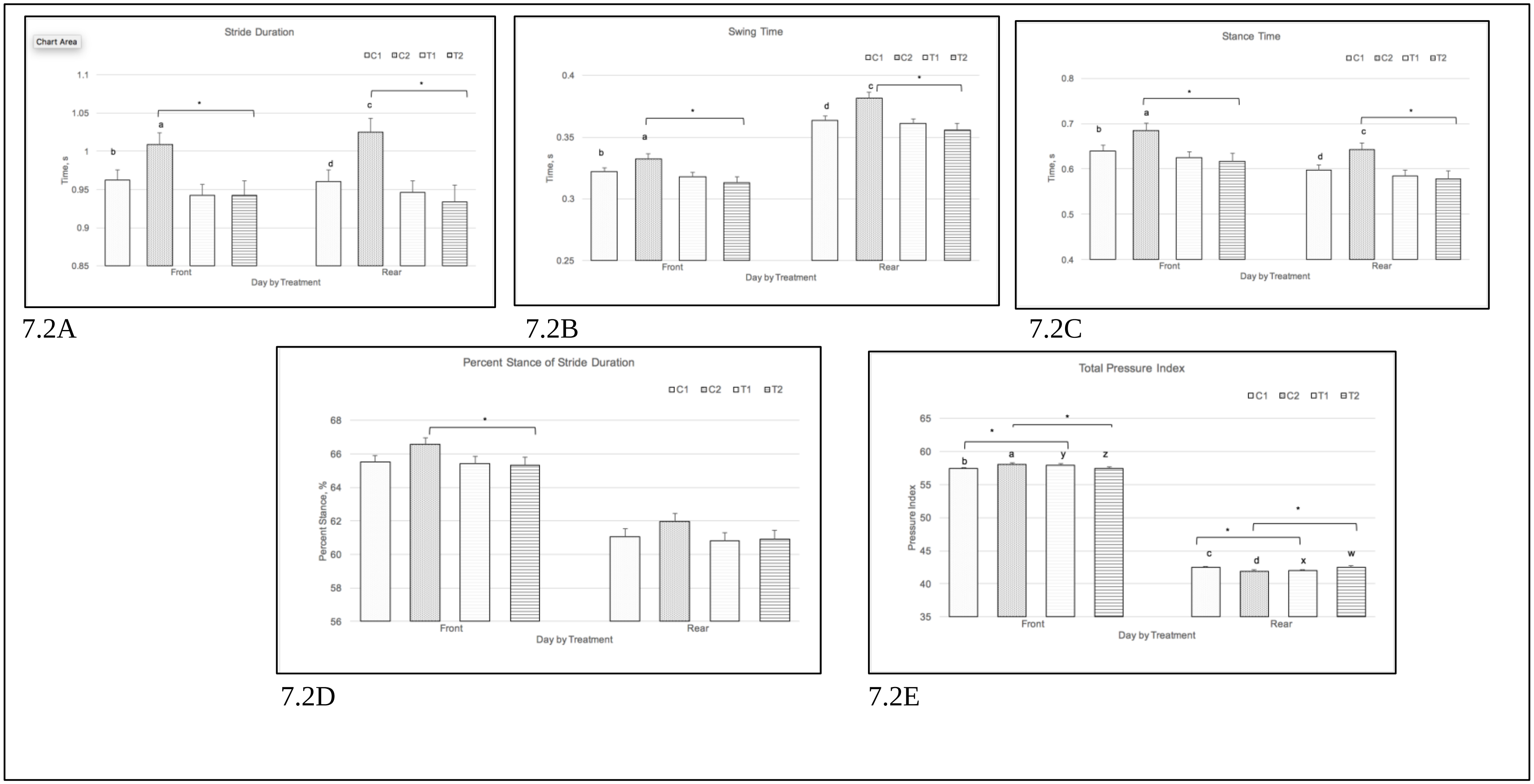
Figure 7.1-Day by treatment for velocity and stride length



7.1A 7.1B

A-Velocity for control first parity, control second parity, treatment first parity and treatment second parity sows. From first parity to second parity there were no significant differences for both treatment and control sows for front and rear limbs. The star and bracket denote that $P < 0.05$ for second parity control sows compared to second parity treatment sows. B- Front and rear stride lengths for control first parity, control second parity, treatment first parity and treatment second parity sows. $P < 0.05$ for both front and rear limbs from first parity to second parity for both parities. There were no significant differences between the two treatments.

Figure 7.2- Treatment and control sows gait parameters for both parities.



Letters denote P < 0.05 within group, asterisks denote P < 0.05 between groups. A: stride durations, B: swing time, C: stance time, D: percent stance, E: total pressure index

CHAPTER 8

Conclusion

Overall, gait analysis can be a useful tool for studying gait quality. From the first study, it has been shown that training pigs was not effective for providing consistent data during the week of training. This means that more training may be needed for the pigs to provide reliable data for the methods that were used. The second study following the pigs across the weight points showed that all gait values change across time, so to be able to use these values, a formula or ratio may need to be developed. The third study showed that there were significant differences in behavior and gait quality based on gender and sire line. This has major implications for working with pigs within the commercial setting. The fourth study about trimming, showed that blunt trimming does not provide the necessary changes to the claw to improve gait quality. The last study of feeding the amino acid mineral complex illustrated that the addition of the amino acid mineral complex was beneficial to gait quality from the first to second parity of the sows. These studies are important for the swine industry as they provide a guide post to future studies that can be run to help gait analysis be integrated into the commercial farm setting. These studies also show methods that are helpful in preventing and treating lameness.