Aus dem Department für Kleintiere und Pferde

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(Leiterin: Univ.-Prof. Dr. med. vet. Florien Jenner, Dipl. ACVS, Dipl. ECVS)

Under pressure:

Evaluation of the forces exerted on the horseback by a conventional dressage saddle and three leather tree dressage saddles

Diplomarbeit

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Ursula Höberth

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Supervisor:

A. Univ. Prof. DI. Dr. Christian Peham

Veterinärmedizinische Universität Wien

Department für Kleintiere und Pferde

Universitätsklinik für Pferde

Movement Science Group

Reviewer:

Priv.Doz. Dr.med.vet Barbara Bockstahler, Dipl. ECVSMR, ACVSMR

Veterinärmedizinische Universität Wien

Department für Kleintiere und Pferde

Universitätsklinik für Kleintiere

Klinische Abteilung für Kleintierchirurgie

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Vienna, 09.09. 2024 Ursula Eva Höberth

Dedication

This project so very dear to my heart would not have been possible the support of my friends and my family.

Many thanks to my friends Hannah and Sabine, who supported this study as rider and saddler and who not only believed in this project from day one, but also spent countless hours with me collecting data. Enthusiasm works better together.

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Zusammenfassung

Die vorliegende Diplomarbeit untersuchte den Einfluss verschiedener Sattelbaumarten auf die Druckverteilung auf dem Pferderücken. Genauer gesagt wurden durch Messungen mit einer Druckmessdecke die durchschnittliche Größe der durch den Sattel beladenen Fläche, die Größe der Fläche, auf die Drücke über 11 Kilopascal einwirkten, sowie der Durchschnittsdruck und der Maximaldruck für den jeweils zum Pferd gehörigen klassischen Dressursattel und drei Lederbaum-Dressursättel ermittelt. An der Studie nahmen insgesamt 12 Reitpferde im Alter zwischen 6 und 15 (10 ± 3) Jahren teil, die vorab einer kurzen allgemeinklinischen (Atem- und Pulsfrequenz, innere Körpertemperatur, Schleimhäute) sowie einer orthopädischen Untersuchung unterzogen wurden. Zusätzlich wurde bei allen Probanden eine objektive Lahmheitsevaluierung mit dem universitätseigenem EquiGait-System durchgeführt und die dabei aufgenommenen Videos von einer erfahrenen Orthopädin zweitbefundet. Die Datensammlung erfolgte im Halten (mit und ohne Reiterin) und im Trab. Zusätzlich wurde eine Berechnung der Auslenkung des Druckmittelpunkts im Trab durchgeführt.

Die im Vorfeld aufgestellten Hypothesen, die besagten, dass die Lederbaumsättel den Druck auf eine kleinere Fläche verteilen würden als der getestete konventionelle Dressursattel, dabei größere Flächen mit Drücken über 11 Kilopascal erzeugen würden und insgesamt höhere durchschnittliche und maximale Drücke auf den Pferderücken übertragen würden, konnten nicht durch die erhobenen Daten bestätigt werden, da keine statistisch signifikanten Unterschiede zwischen den vier getesteten Sätteln feststellbar waren. Im Stand war die durchschnittliche durch den Sattel beladene Fläche 722.5 (± 35.9) cm² groß, die durchschnittliche Größe der Fläche mit Drücken über 11 kPa war 225.4 ± 16.3 cm² groß, der durchschnittlich gemessene Druck belief sich auf 0.3 ± 0.025 N/cm² und der durchschnittliche Höchstdruck lag bei 3.5 ± 0.2 N/cm². Im Trab war der durchschnittlich durch die Sättel ausgeübte Druck 0.5 ± 0.024 N/cm² groß und der durchschnittliche Maximaldruck lag bei 4.5 ± 0.2 N/cm². Im Gegensatz dazu zeigten die Berechnungen zur Auslenkung des Druckmittelpunkts signifikante Unterschiede zwischen den Sätteln und in Hinblick auf die Sattelseite (linke vs. rechte Seite des Sattels) und die Richtung (craniocaudale vs. laterolaterale Richtung). Der konventionelle Dressursattel wies einen größeren Bewegungsradius auf als die drei getesteten Lederbaumsättel und legte mit 286.5 ± 7.2 mm die größte durchschnittliche Distanz zurück. Dahinter folgten der Lederbaumsattel C (270.2 ± 10.1 mm) und dem Lederbaumsattel A (249.6 ± 11.9 mm). Der Lederbaumsattel B bot dem

Reiter am meisten Stabilität (246.8 ± 9.9 mm). Während es keine statistisch signifikanten Unterschiede zwischen den drei getesteten Lederbaumsättel gab, schnitten die Lederbaumsättel A und B deutlich besser ab als der konventionelle Dressursattel. Die Auslenkung des Druckmittelpunkts war auf der linken Seite (durchschnittlich 277.1 ± 6.8 mm) größer als auf der rechten Seite (durchschnittlich 249.4 ± 10.9 mm) und in der anterioposterioren Richtung (durchschnittlich 329.1 ± 10.9 mm) größer als in der laterolateralen Richtung (durchschnittlich 197.4 ± 8.3 mm).

Zusammenfassend kann also gesagt werden, dass die getesteten Lederbaum Dressursättel den beim Reiten auf den Pferderücken einwirkenden Druck genauso gleichmäßig verteilen wie ein an das Pferd angepasster und regelmäßig kontrollierter konventioneller Dressursattel und darüber hinaus den Reiter stabiler auf dem Pferd positionieren.

Abstract

This diploma thesis examined how saddle tree construction affects saddle performance as interface between horse and rider. Four dressage saddles – three leathertree and one conventional – were compared based on a set of variables including the average size of the loaded area, the average size of the area with pressures above 11 kilopascals as well as the average and maximum pressures at halt (with and without rider) and at trot (with rider). Furthermore, the range of motion of the rider's center of pressure at trot was analysed.

Twelve horses aged 6 to 15 years (mean ± SD: age 10 ± 3 years) that were habitually used for dressage and/or leisure-riding were tested using a pressure mat. Prior to their inclusion, all horses were evaluated as fit to perform and serviceably sound by undergoing a brief clinical (respiratory rate, pulse, body temperature and mucous membranes) as well as an orthopaedic examination. Additionally, they had to pass an objective lameness assessment at trot. This lameness assessment was also filmed using a mobile phone and shown to an experienced specialist in equine orthopaedics so as to make sure that the horses were fit to be used in the trial.

It was hypothesized that, compared to the conventional dressage saddle, the leathertree dressage saddles would create a smaller loaded area, a larger area with pressures above 11kPa as well as higher average and maximum pressures. The data collected at halt and at trot supported none of these hypotheses and revealed no statistically significant differences between the tested saddles. At halt, the average loaded area was 722.5 (± 35.9) cm², the average size of the area with pressures higher than 11 kPa was 225.4 ± 16.3 cm², the average pressure was 0.3 ± 0.025 N/cm² and the average maximum pressure was 3.5 ± 0.2 N/cm². At trot, the average pressure exerted by the tested saddles was 0.5 ± 0.024 N/cm² and the average maximum pressure was 4.5 ± 0.2 N/cm².

However, the range of motion of the rider's center of pressure was significantly influenced by the choice of saddle, the side of the saddle (left vs. right) and the direction (craniocaudal vs. laterolateral). The conventional dressage saddle allowed the largest average range of motion (286.5 ± 7.2 mm), followed by leathertree saddle C (270.2 ± 10.1 mm) and leather tree saddle A (249.6 ± 11.9 mm). Leathertree saddle B offered the highest degree of stability to the rider (246.8 ± 9.9 mm). While there was no statistically relevant difference between the three tested leathertree dressage saddles, both leathertree saddle A and leathertree saddle B performed

significantly better than the conventional dressage saddle (p-values: 0.025 and 0.002 respectively). The excursion of the COP was larger on the left side of the saddle (mean value of 277.1 ± 6.8 mm) than it was on the right side (mean value of 249.4 ± 10.9 mm) and larger in the anteroposterior direction (mean excursion of 329.1 ± 10.9 mm) than in the laterolateral direction (mean excursion of 197.4 ± 8.3 mm).

All in all, the tested leathertree dressage saddles distributed the pressure as evenly as the conventional dressage saddle but offered more stability to the rider.

List of abbreviations

Con	conventional dressage saddle
COP	center of pressure
kPa	kilopascal
LA	leathertree saddle A
LB	leathertree saddle B
LC	leathertree saddle C
N	newton
ROM	range of motion

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1. Introduction

The question whether a saddle fits a horse has long been debated among riders, trainers and even among experienced saddlers. The complexity of the topic is also reflected in the broad spectrum of research that has been carried out in the field of saddle fit. While some of the research conducted has focused mainly on describing and evaluating systems that measure the pressures and forces exerted on the back of the horse, other studies have scrutinized the rider's effect on both the kinematics of the horseback and the amount as well as the distribution of pressure on the horse's topline. A considerable amount of research has also explored how saddle equipment – such as saddle pads or half pads –, panel design, girth attachment and the type and construction method of the saddle tree affect fit and function.

The present study aimed at considering how the way a saddle tree is constructed influences the way a saddle functions as a link between horse and rider. Specifically, it compared saddles with leathertree to standard saddles. Former research (1–4) has clearly suggested that treeless saddles or saddles with a very high degree of flexibility tend to distribute the rider's weight less evenly than saddles with a conventional saddle tree and create pressure peaks that are detrimental to the horse's performance and health. However, there has been no research on the performance of saddles with leathertrees, and the variety of non-traditional saddle tree constructions on the market complicates comparisons with earlier studies (3).

1.1 Research questions and hypotheses

To evaluate the performance of leathertree dressage saddles compared to conventional dressage saddles, it makes sense to follow a methodology suggested by Belock et al. in 2012 (2). This involves considering the size of the saddles' loaded area, the average as well as the maximum pressures exerted on the horseback and the size of the area where pressures above 11 kPa register, and comparing these to the values that can be obtained for the conventional dressage saddles that are usually used in the training of the horses.

These measurements were taken for the three leathertree dressage saddles and the conventional dressage saddle in a standing position with and without rider as well as in ridden trot. By testing three different leathertree dressage saddles, the study aimed to minimize bias related to the compatibility of individual saddle models with the horses used in the study.

The hypotheses were the following:

a) Compared to a dressage saddle with a conventional saddle tree, the leathertree dressage saddles create a smaller loaded area, thus distributing the incoming forces less effectively than the conventional saddles do.
b) Compared to a dressage saddle with a conventional saddle tree, the leathertree dressage saddles create a higher average pressure on the horseback.
c) Compared to a dressage saddle with a conventional saddle tree, the leathertree dressage saddles create a higher maximum pressure on the horseback.
d) Compared to a dressage saddle with a conventional saddle tree, the leathertree dressage saddles create larger areas where pressures over 11 kPa register.
e) Given a) – d), none of the leathertree dressage saddles distributes the pressures exerted on the horseback as evenly as the respective conventional dressage saddles used for the horses do.

2. Literature review

2.1 Horseback in motion: a biomechanical marvel disturbed by the rider?

In order to grasp the complexity and challenges of saddle construction and saddle fit, it is vital to have a basic understanding of the biomechanics of the horseback (5). Every movement phase that makes up the walk, trot and canter of a horse produces a typical biomechanical situation in the back of the animal that is characterised by a finely coordinated interplay of flexion, extension, lateral bending and axial rotation (6–10).

Given that the trot is a two-beat diagonal gait, it is ideally suited to compare symmetry of movement and symmetry of pressure distribution under a saddle. At trot, maximal back flexion can be noticed during the swing phase (10). At the beginning of the stance phase in trot, the spinal column is in extension (7). Maximal extension occurs when the forelimb and the diagonal hind limb are weight bearing (10–12). While back extensors moderate flexion, back flexors moderate extension so as to ensure postural control (10). Later in the stance phase, the spinal column undergoes counter rotation, starting caudally at the sacrum, then continuing with the lumbar spine and finally the thoracic spine (7).

Rider influence changes these basic physiological patterns (5). If the horse is being ridden, it bears not only the accelerated mass of the horse's intestines, but also that of the rider and the saddle. The added weight can alter the horse's movements, particularly if it is not yet well trained or not equipped with a well-fitted saddle that enables them to develop the musculature and balance needed to carry a rider without incurring damage. The same happens under a heavy or inexperienced rider.

Martin et al. showed that as the rider applies pressure on the horseback, back movements lessen in an attempt to counteract the force created by the acceleration of the rider (5). In a study where De Cocq et al. collected pressure data at walk, trot and canter under four conditions, one being with the horse carrying 75kg of weight while moving on a treadmill at trot, it was shown that weight had an extending effect on the horseback and led to an increased, compensatory retraction of the forelimbs accompanied by a lesser increase in retraction of the hindlimbs and protraction of the forelimbs (13). The increased extension that occurs when a non-actively arched horseback is loaded obviously is of potential clinical relevance, not only because it comes with a higher degree of convergence of the spinous processes of the thoracolumbar vertebrae and may therefore provoke the development of kissing spines, but also because it may lead to stress and tensions in the ligaments and musculature of the equine

top line (13). Furthermore, it potentially causes compensatory movement patterns that can ultimately lead to back pain, performance problems an lameness. Even respiratory problems can be a consequence of a hollow back, as the diaphragm, which plays an important part in the process of inspiration, is attached to the diaphragmatic vertebra. This vertebra happens to be in the area where the saddle is positioned and can block due to unphysiological loading of the back. In a study performed in 2017, Murray et al. were able to show that saddles that manage to relieve the region where peak pressures can be detected at trot (i.e. the region axially to the 10^{th} to 13^{th} thoracic vertebrae), have a positive influence on horse kinematics in trot, increasing forelimb and hindlimb protraction, carpal and tarsal flexion and thoracolumbar expansion after exercise (10).

It is also during the stance phase at trot that the overall forces both saddle and rider exert on the horseback increase drastically on the cranial part of the back, and do so on the side of the landing ipsilateral hindlimb (14). The combined weight of rider and saddle, which at some point during this phase is pushed cranially, approaches the horse's scapula which will undergo backward rotation in the following suspension phase. This can therefore aggravate any existing fit problems especially in the cranial aspect of the saddle. Later in the stance phase, when the spinal column undergoes counter rotation (starting caudally at the sacrum, then continuing with the lumbar spine and finally the thoracic spine, (7)), there is an increase of pressure in the caudal part of the horseback (14). These changes in pressure throughout the movement phase underscore the importance of a well-fitted saddle.

Additionally, rider weight and skill impact pressure distribution. Frühwirt et al. found out that both the maximum overall force exerted and the center of pressure follow certain gait-specific patterns and that, generally, forces increase with velocity (15). These findings were supported also by Roost et al. (16). While at walk the overall force equals more or less the body mass of the rider, the force is twice as high at trot and even higher at canter (15). Another study has demonstrated that there is a positive correlation between the rider's bodyweight and the pressure exerted on the horseback (16).

The rider's body mass influences the horse's kinematics immensely, especially so at a higher speed. In a study performed by Roost et al., where four riders of equal skill rode a total of six horses, the two heaviest riders did not manage to get all horses to canter. Only two thirds of the participating horses cantered with the heavy and only one horse cantered with the very heavy rider (16). The same study showed that a saddle that is too small for a rider has no

chance of distributing the rider's weight evenly even if it fits the horse perfectly. It then distributes the body mass atypically with regard to the gait and basic position of the rider, putting more pressure on the caudal part of the horseback than it would with a rider it actually fits for. Even at rising trot, where the pressure exerted by the rider usually automatically shifts more towards the cranial aspect of the horseback (17), the pressure created by the very heavy rider was similar cranially and caudally (16), thus putting significant strain on the anyways more sensitive caudal region of the saddle area (18). A higher weight of the rider, however, not only creates unusal pressure distribution patterns, but potentially also provokes focal pressure peaks, which are known to lead to alterations in the motion pattern of the horse. Research by Frühwirt has shown that the horse shortens the length of its strides if the saddle exerts focal pressure (15). Another study by Dyson et al. even found that excessive rider weight can cause lameness in otherwise sound horses (19).

2.2 Poor saddle fit and the problems it causes

Given how saddle fitting is still mostly performed on a standing horse (15) and given that even a saddle that perfectly fits a horse in a standing position shifts as horse and rider move together, it it quite easy to imagine the problems that can come with saddles of poor fit.

While Peham et al. demonstrated that a good rider can have a stabilizing effect on the horse, effectively leading to the horse showing less variation in its motion pattern, a non-fitting saddle can have the opposite effect and disturb the horse-rider-communication greatly (20). In the worst case, an ill-fitting saddle not only presents an impediment to harmony, but also scauses short-term or even long-term problems with the horse. Signs of ill-fit are known to range from hypersensitivity when being groomed, nervosity or aggression when being saddled or even only approached by the rider with the tack, to dry patches on the back after riding, ruffled hair in the area where the saddle is positioned or even saddle-soreness and muscle atrophy (21).

Former research has suggested that mean pressures exceeding 11 kPa (1 kPa equaling 0.1 N/cm²) are likely to have a negative effect on the horse's health (17,18,22). Equally, studies performed in the field of human medicine can provide us with useful information as to where tissue integrity is in jeopardy. Some research has shown that constant pressures of more than 32 mmHg (i.e. 4.3 kPa) over more than two hours could be linked to significant damage done to skin and underlying musculature (23,24), while other research found that pressures exceeding the mean capillary pressure of 4.7 kPa may lead to vascular occlusion and thus

ischemia and ultimately tissue necrosis (25). Notwithstanding which values are more accurate, it is important to remember that there is an inverse relationship between the amount of pressure and the period during which it applies and that the constant switch between loading and unloading of areas that happens during ridden exercise renders pressure less problematic (4).

Even though poor saddle fit frequently contributes to diminishing performance, it is often overlooked (26), at least until backpain or lameness occur. In a study performed in 1997, Harman examined the saddles of a total of thirty horses presented to her with backpain or performance problems and found out that over 70% of the saddles displayed manufacturing faults, uneven flocking or wear. More than half of the saddles had several problems at once and approximately one third of the saddles presented generally did not fit the shape of the horses' backs. Only about 16 % of the tested saddles were a good to excellent fit for the horses they belonged to (27).

Another study performed by Nyikos et al. in 2005 also focused on horses with backproblems. 26 horses first underwent a clinical examination and were then trotted under a total of 29 saddles. During the examination, 19 horses showed tension in the back, six in the musculature of the cervical spine and four around the neck. Regarding the problems that became apparent on the back, they were mostly observed in the area where the saddle is positioned. Furthermore, the pressure data collected showed that mean pressures exceeding 1.0 N/cm² and maximum pressures exceeding 2.2 N/cm² in the caudal third of the saddle sufficed to create tension in the lumbar spine, while the cranial third of the saddle area tolerated pressure slightly better, with maximum pressures of over 3.45 N/cm² and mean pressures of over than 1.32 N/cm² leading to backpain in the horses studied (18).

Sometimes, the lack of performance is attributed to management factors other than saddle fit. For Greve, knowledge of the horse-saddle-rider-interaction is limited and not only saddle-related factors, but also rider- and horse-related factors play a role when it comes to poor performance (28). Harman, on the other hand, goes as far as to say that most of the difficulties people experience when training horses, among them unwillingness or unability to round the back, muscle atrophy or lack of muscular development inspite of a sufficient amount of training as well as refusal to jump fences, are related to pain and ill-fitting saddles (24,27). Equally, uneven hoof wear and respiratory problems, which also contribute to the poor-performance-syndrome of the horse, can be linked to saddles that do not properly fit the horse-rider-team

(24), and there is a consensus that stress – which may also come from painful states such as being ridden with unfitting equipment – is apt to create internal problems such as EGUS or colic in horses (29).

Among the long-term indicators of improvable saddle fit, muscle atrophy of the trapezius and longissimus dorsi muscles or depressions elsewhere under the saddle rank high up on the list (21). The fact that there is a physiological increase in the activity of the longissimus dorsi muscle in the second half of the stance phase at trot (6) with a measurable peak of activity around the 12th thoracic vertebrae (30), i.e. the area where saddle and rider typically have their center of gravity, means that a horse equipped with a poorly fitting saddle is caught in a vicious circle: while the movements it is asked to perform mean pushing potentially already sore musculature against a saddle that causes pain, any attempt to escape this very pain by changing its physiological movement pattern may lead to further tensions, pain and ultimately harm to its body. This happens because the body's joints and tendons are overstrained in an attempt to handle the forces that come with dysfunctional movement patterns. Research done in human medicine has shown that pressure exerted on musculature pentetrates the tissue and even increases as it reaches the underlying bones (15). This means that the pressures we measure under saddles, some of them already so high that they compromise the horse's health (17,18,22), do not even provide the full picture of what the horses' bodies have to cope with while being ridden with an ill-fitting saddle.

2.3 The fitting saddle – a mission impossible?

There is a consensus that, in order for a horse to be a happy athlete or even a reliable partner for leisure time, it needs to be equipped with a saddle that fits both animal and rider.

But what are the most important qualities of a saddle that fits?

The angle of the saddle tree should match the form of the horseback (14) so as to offer enough distance between the withers and the saddle channel on the one hand and enough space for the rotation of the scapulae on the other hand. If the gullet width is too narrow, the proximal part of the scapula hits the saddle during swing phase instead of unimpededly rotating underneath it. Furthermore, the saddle panels should be evenly flocked, soft and symmetrical, so that they are in full, largesurface contact with the horseback (14,18,27). Manufacturing faults, uneven or clotted flocking can cause discomfort (27) and can lead to significantly higher

pressures under the saddle (18). Likewise, asymmetrical flocking leads to uneven distribution of the rider's weight and even to a decreasing mobility of the cervical spine (18). The channel should be wide enough and allow for sufficient space along both sides of the spinal column (31) so that its physiological lateral excursion can take place while the horse is in motion (20). The radius of both saddle and horseback should be compatible (27) so that bridging and wiggling can be avoided and pressures under the saddle should remain constantly low throughout the whole motion cycle so that no excessive focal pressures are created. (18,22)

Research has shown that this ideal is often attempted, but seldom achieved (18,27). As a consequence, both the market and the scientific community have tried to tackle this problem. This is reflected in the apparently infinite number of available products on the market on the one hand, and the myriad research done on how equipment or novel construction principles for saddles influence saddle fit on the other (1–5,13,17,24,28,32–38). Since the 1990s, the scientific community has put a lot of effort into making objective statements about saddle fit, some defining the maximal total force (15,32), others focal high pressure (27,39) as the most telling variable when it comes to saddle fit.

The first one to use electronic pressure mats in order to collect objective data was Harman (24), and in the years to follow the technology was used to investigate the relationship between pressure distribution and various aspects of saddle construction (2,4,5,10,17,18,22,34). For her studies, Harman used a pressure mat produced by the company Saddletech (24,27). Later, some studies used a pressure mat by the company Vistamed, which could be operated wirelessly, however did not offer ideal levels of usability (regarding the process of calibration) and reproducibility (40,41). Since the early 2000s, most studies have used the Pliance system of the company Novel GmbH, which equally allows the horse to move freely.

Regarding noteworthy trends on the market, one certainly has been the creation of more flexible or even treeless saddles. The line of argumentation has been that a treed saddle, while it certainly can provide stability for the rider and help distribute their weight evenly and over a large area if it fits a horse well (34), it potentially cannot, due to its stiffness, adapt to the changes the horseback undergoes while the horse is in motion (28) or when the horse, for some reason, gains or loses weight or muscle mass. It has been argued that even a saddle that used to perfectly respect and support the horse's anatomy and biomechanics, can, for one reason or another, become a misfit. Also, the idea has been to create saddles that fit various back shapes (28). As a consequence, saddle designers introduced a variety of saddle designs

which supposedly serve as more adaptable interfaces between horse and rider, some with only rudimental trees (28), others with no tree at all. In order to ensure horse-welfare, it is important to understand how individual designs behave on the horseback (26), and among the many designs available on the market, some have become the object of scientific scrutiny.

In 2010, Latif et al. (1) performed a study in which they compared a race saddle with a wooden tree, a race saddle with no tree (however with headplate) and a racing saddle with a flexible synthetic tree at rising trot, canter and gallop. While the saddle with the flexible synthetic tree offered the best mean pressure distribution of the three tested saddles, the treeless saddle with only a headplate tended to concentrate the pressure on localised areas of the horseback depending on the position of the rider. Other studies could witness a similar phenomenon in conventional dressage saddles with excessively wide trees (22) and also when horses were ridden without saddle (34). The race saddle with the wooden tree proved to be equally inappropriate for the horses used in the study as its radius was too large and it therefore exhibited bridging. Overall, this study found that treeless saddles were inferior to treed saddles which fit the horse.

There was another study performed in 2013 by Ramseier et al. which compared the effects of limb kinematics and the saddle pressure patterns of three saddles used on 12 Icelandic horses on a treadmill at walk and tölt (3). The saddles assessed were an Iceland saddle (typically centering the rider's mass in the caudal part of the saddle), a treeless saddle cushion and a dressage-style saddle. While the treed saddles put more pressure on the hind part of the saddle area, the treeless saddle cushion exhibited a tendency to put most pressure cranially on the horseback and distributed only little force to the caudal part of the saddle even though the riders were sitting in the middle of the saddle. None of the tested saddles had an influence on the limb kinematics.

Another study performed by Belock et al. in 2012 compared the force and pressure distribution of one conventional dressage saddle (used on all eight Arabian horses which participated in the study) and one treeless dressage saddle at sitting trot (2). The treeless dressage saddle used had been produced by the US-based company *Ansur Saddlery* (model "Carlton"). *Ansur* saddles are, according to the company's website, constructed using the so-called *Flex-Core-Technology*, which consists of "the core structure and the trauma system" and creates a "semi-firm but flexible-in-all-directions foundation upon which the finished treeless saddle is built" (42). The basic construction principles are explained in more detail in the corresponding patent

(43). The study found that the conventional dressage saddle distributed the rider's weight over a significantly larger area on the horseback with fewer sensors recording mean pressures over 11 kPa and also that the mean and maximal pressures excerted by the conventional saddle were lower.

Finally, in 2014, a study by Clayton et al. again compared a conventional treed dressage saddle to a treeless *Ansur* dressage saddle, this time, however using the model "Ansur Excel" (4). Even though there were no differences regaring the size of the contract area or any of the force variables between the two tested saddles, the mean pressure over all sensors, the maximal pressure on any individual sensor and the area with mean pressures exceeding 11 kPa were significantly larger for the *Ansur* model. The high pressure areas were regarded as being caused by the narrow gullet and the highly-sloped panels of the treeless saddle (4).

2.4 The leathertree saddle: Just another attempt at going treeless?

To date, no studies have specifically assessed the performance of leathertree saddles with regard to pressure or force distribution. But what, exactly, is the difference between leathertree saddles and conventional saddles or other types of non-conventional saddles?

When the German examination regulations for performance tests in equestian sports define how a saddle is constructed, the saddle tree and the stirrup bar which is attached to the saddle tree are mentioned among the defining parameters (44). Conventional saddles furthermore consist of a gullet and a gullet plate which stabilises the pommel. Depending on the material used for the construction of the saddle tree (wood, fibreglass, carbon to name only a few), the tree is more or less rigid. Treeless saddles, on the other hand, contain no saddle tree and also very often no or only few rigid elements such as a gullet plate (2), depending of course on the manufacturer and the intended use of the saddle.

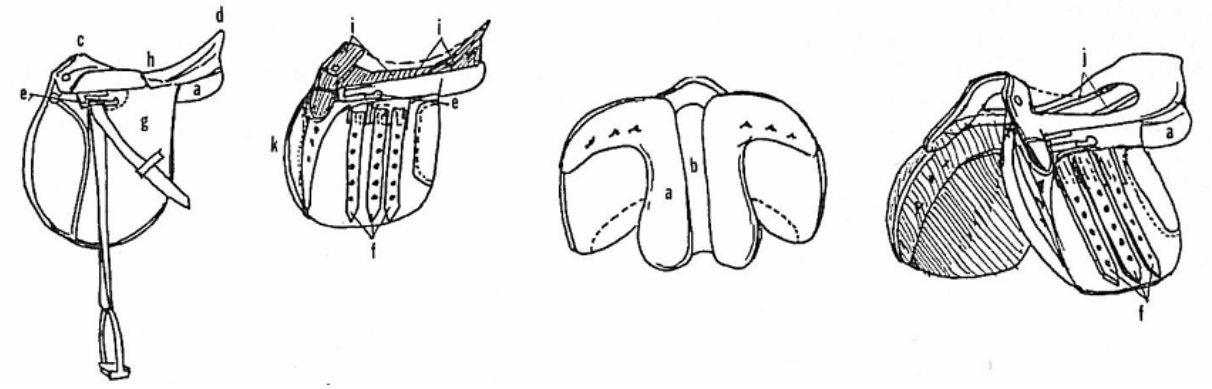


Fig. 1: Views of a typical English saddle and its parts (27): a) Panel, b) Gullet, c) Pommel, d) Cantle, e) Stirrup bar, f) Billets, g) Flaps, h) Seat, i) Tree, j) Spring of tree, k) Knee roll

Leathertree saddles are often lumped together or confused with treeless saddles. However, they offer more stabilising elements than treeless saddles and they contain a leathertree, which renders them less malleable and more stable. As the integrated tree is not made of wood, more or less rigid synthetic materials or a combination thereof, but rather of one or more layers of sturdy leather, it is more flexible than a conventional saddle tree but still relatively stable in form. Leathertree saddes are able to adapt to the horseback through body heat so that they will adjust to the topline over time. Additionally, leathertree saddles contain a shaping element to which the stirrup bar is attached and which is available in different sizes and angles so that it fits the shape of the horseback. They do not, however, contain a gullet plate.



Fig. 2: Leathertree of a *Hidalgo* riding saddle (Spanish model), kindly made available by Dr. Nina Holzer, owner and founder of the *Hidalgo*-company (45)

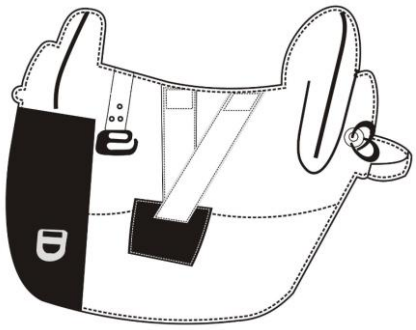


Fig. 3: Basic design of a *Hidalgo* riding saddle (Spanish model) incl. stirrup bar and girthing system, kindly made available by Dr. Nina Holzer, owner and founder of the *Hidalgo*-company (45)



Fig. 4: Various shaping elements/stirrup bars of a *Hidalgo* riding saddle, kindly made available by Dr. Nina Holzer, owner and founder of the *Hidalgo*-company (45)

Given how the construction principles differ between treeless saddles and leathertree saddles, it was the goal of the present study to see in how far the results obtained in previous studies for the treeless saddles (1–4) hold true for leathertree saddles.

3. Material and methods

This project was approved by the Ethics and Animal Welfare Committee of the University of Veterinary Medicine, Vienna, under protocol number ETK-115/06/2022 and in accordance with the university's guidelines for Good Scientific Practice.

3.1 Rider

In order to avoid variability due to rider's bodymass (40) or level of proficiency (46), one experienced female rider (certified trainer of classical dressage, bodymass 48 kg, height 1,64 m) rode all the horses included in this study.

3.2 Horses

The 12 horses used in the study were of a variety of breeds, between 6 and 15 years old (mean ± SD: age 10 ± 3 years) and habitually used for dressage and/or leisure-riding (Tab. 1).

Tab. 1: Breed, sex, age and use of the horses included in the study

	Breed	Sex	Age (years)	Use
Horse 1	Haflinger-Quarter	gelding	15	dressage/leisure
Horse 2	Lusitano	gelding	13	dressage/leisure
Horse 3	Lusitano	gelding	12	dressage/leisure
Horse 4	Oldenburger	mare	10	dressage
Horse 5	Lusitano	stallion	10	dressage
Horse 6	Lusitano	gelding	9	dressage
Horse 7	Oldenburger	gelding	12	dressage/leisure
Horse 8	Pura Raza Espagñola (PRE)	gelding	9	dressage/leisure
Horse 9	Lusitano	gelding	8	dressage
Horse 10	Haflinger-Icelandic-Paint	gelding	7	dressage/leisure
Horse 11	Cruzado	gelding	6	dressage/leisure
Horse 12	PRE-Lusitano	mare	8	leisure

All participating horses were evaluated as fit to perform and servicably sound prior to the data collection. In order to ensure this, they underwent a brief clinical (respiratory rate, pulse, body temperature and mucous membranes) as well as orthopaedic (adspection while standing and walking on a straight line, palpation of forelimbs, back and hindlimbs) examination. Additionally, they had to pass an objective lameness assessment at trot, using the university's EquiGait system. This lameness assessment was also filmed using a mobile phone (Samsung

Galaxy S10 with a 12 megapixel 45° telephoto camera, 2x zoom, OIS anti-blur-software lens (47)) from a distance of 15 meters from the horses. Filming was done from the three perspectives customary during lameness examination: the front, the hind and the side of the horse.

The EquiGait system (https://equigait.co.uk/) is a validated, inertial sensor system which has been developed by Dr. Thilo Pfau from the Royal Veterinary College London to study gait symmetry (48,49). It can be used to detect changes in movement patterns as well as even subtle signs of assymetry or lameness (50) by providing quantitative data on both vertical movement symmetry and vertical displacement over a number of strides at trot (51). The University Equine Hospital of the University of Veterinary Medicine Vienna uses the three-sensor version of the Equigait system, where the sensors are non-invasively positioned on the poll, the withers and the sacrum, and the collected data are wirelessly transferred to a computer where they are analysed.



Fig. 5: EquiGait System, here in exemplary set-up with five sensors (52)

There are various definitions of lameness, but it is mostly defined as a deviation of the movement pattern of the horse that stems from a functional or structural problem of the locomotor system and orthopaedic pain (53,54). It is not clear what degree of asymmetry is clinically relevant (51). For the purpose of this study, freedom from lameness was defined as

showing deviations from symmetry of *a)* ≤ 16 mm *and b)* ≤ 20% (i.e. 50% of all collected strides must not exceed 20% asymmetry (55)) according to the EquiGait analysis. In addition to the subjective and objective lameness evaluation described, an experienced specialist in equine orthopaedics was asked to review the videos of those horses which had narrowly missed the criterion set for the Equigait examination. Upon review of the videos, twelve horses (see table 1) were deemed fit to participate and were thus included in the present study.

A sample protocol for the subjective parts of the examination as well as the EquiGait protocols of the participating horses can be found in the annex.

3.3 Electronic devices

In order to collect the data, an anatomically shaped pressure mat by the company *medilogic*® (T&T medilogic Medizintechnik GmbH) was used. The saddle mat is flexible, 880mm by 790 mm in size and has a measuring surface that covers 680 mm by 710 mm. It furthermore consists of a total of 480 SSR-sensors that, supplied by a 9V standard battery, can measure pressures between 0.2 and 8 N/cm². In order to perform measurements, the mat is positioned between saddle and horseback like a saddle blanket. The collected data are then wirelessly transmitted to a computer on which the *medilogic*® software has been installed prior to the measurements. A video camera which is connected to the computer allows to allocate the movement phase to the recorded pressure pattern. As the riding sequences are recorded, it is possible to analyze the colour-code pressure distribution patterns together with the synchronous video capture either live or via play-back. In order to perform a more detailled data analysis, it it possible to subsequently export the collected data as Excel-files.



Fig. 6: Exemplary visual representation of the pressure distribution during data collection. The colour code serves as a rough indicator of how much pressure (N/cm²) acts on the different parts of the horseback at that moment. (56)



Fig. 7: Anatomically shaped *medilogic*® pressure mat (56)

3.4 Saddles and saddle blankets

A total of four saddles were evaluated per horse: the horse's own dressage saddle with a conventional, more or less rigid saddle tree and three leathertree dressage saddles which were fitted to each horse individually by a professional saddler accompanying the project. While the horses' own saddles were of various renowned brands (*Albion, Amerigo, Childeric, Kentaur, Kieffer, Passier, Trieb, Signum, Wintec*), the same three adaptable leather tree saddles were used for all horses. These were the model "Event", produced by the German-based company *Sorenta Sattel* (Leathertree dressage saddle A, Fig. 8), the model "Venice Spezial", produced by the Austrian-based *Hidalgo*-company (Leathertree dressage saddle B, Fig. 9) and the model "Viento" by the German-based company *Sattelglück* (Leathertree dressage saddle C, Fig. 10). Instead of a gullet plate and a conventional rigid saddle tree, the three leathertree dressage saddles feature a saddle tree made of sturdy leather and a shaping element. Furthermore,

they are equipped with a v-girthing system designed to stabilize the saddle on the horseback as well as hook-and-loop foam panels in different lenghts to cater for the horse's individual needs.

For the conventional dressage saddles the data collection took place using the identical "Cotton" saddlecloth (Fig. 11) positioned in between of the saddle and the pressure mat. The three leathertree dressage saddles were equipped with the identical *Grandeur*-saddlecloth (Fig. 12), which was equally positioned between saddle and pressure mat during the collection of the data. The use of a Grandeur saddlecloth or any other adaptable saddlecloth is not a necessity, however it is recommended by the manufacturers of leathertree saddles in order to provide extra clearance for the spine. The *Grandeur*-pad used for this study has four pockets in which inlays can be inserted to ensure a clear spine even in the case of horses with difficult saddle fit. The horses' individual short girths were used to fix all four saddles during the data collection.



Fig. 8: "Event", Sorenta Sattel



Fig. 9: "Venice Spezial", Hidalgo



Fig. 10: "Viento", CE-Sattelglück



Fig. 11: Saddlecloth "Cotton", Eskadron



Fig. 12: Saddlecloth "Physio Pad", Grandeur

3.5 Collection of data

Once it had been established that the horses were fit to participate in the trial (see chapter 3.2), the data collection started. Following earlier research (2,17,18), the decision had been taken to evaluate, for each of the saddles included in this study, the size of the saddles' loaded area, the average as well as the maximum pressures exerted on the horseback and the size of the area where pressures above 11 kPa registered. In order to collect the data necessary to calculate these values, pressure measurements were carried out while the horse-rider team performed a set of exercises:

- standing position with rider (30 seconds)
- standing position without rider (30 seconds)
- ridden trot (sitting trot, three consecutive measurements on a straight line of 30 meters)

Pressure between horseback and saddle was measured using the electronic *medilogic*® pressure mat. Once positioned on the horse back, the mat stayed in position until all of the exercises were completed. Each tested saddle was placed on top of the pressure mat, always starting with the horse's own conventional treed dressage saddle. The girth was carefully tightened, alternating between the left and the right side. When mounting the horses, the rider was lifted into the saddle by a helping person so that both the pressure mat and the saddle would stay in the position arranged by the saddler. Before the measurements started, each horse was warmed up in the area where the tests were performed so that they would get accustomed to the setting and the equipment. Then, after the exercises had been performed with the conventional dressage saddle, the leathertree dressage saddles were adapted to the horses and tested in random order, however in the same manner as the conventional saddle.

For each tested saddle, all exercises mentioned above were performed. When changing saddles, the pressure mat was left on the horse's back. It stayed in place until all of the measurements were completed.

3.6 Analysis of data

The next step was the calculation and analysis of the data. The values obtained during the corresponding measurements were used to evaluate:

- the size of the saddles' loaded area
- the average as well as the maximum pressures exerted on the horseback, and
- the size of the area where pressures above 11 kPa registered.

For the static measurements, the loaded area was calculated as the mean of the sum of all sensors, which, at any point in time, registered a pressure larger than zero N/cm² multiplied by the area covered by one sensor (according to the manufacturer 10.33 cm²). The size of the area which registered above 11 kPa was determined by calculating the mean of the sum of all sensors, which, at any point in time, registered pressures larger than 1.1 N/cm² multiplied by the area covered by one sensor. Furthermore, the maximum as well as the average pressures were determined.

For trot, the range of motion (ROM) of the center of pressure (COP) of the rider was included into the scope. The rider's center of pressure can be defined as the centroid of pressure distribution (57). Better yet, one could say that it represents the point on a surface where the total sum of pressure or force is applied. In other words, it is the average location of all the forces exerted by the body on a supporting surface. The size of its range of motion, especially when represented graphically, adequately demonstrates a rider's stability (57) (and therefore level of proficiency, (20)) and the area where the pressure acts on the horseback:

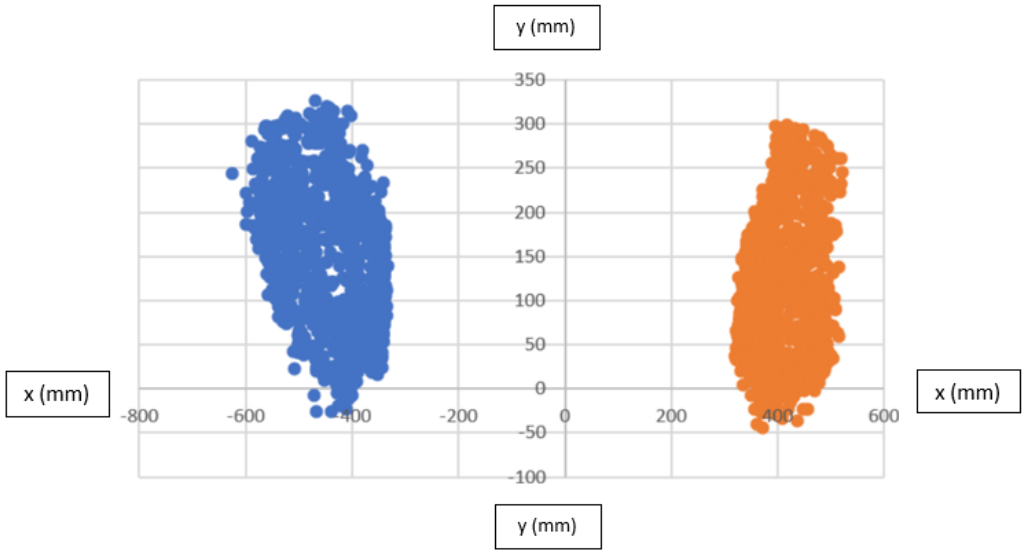


Fig. 13: Example of a ROM (in mm) of the COP during data collection at trot. Every dot marks a coordinate position.

The path of the COP is defined as the difference between the maximal and minimal x and y COP coordinates.

All the above-mentioned values, both measured and calculated, were finally tested for statistical significance and compared between the four saddles.

3.7 Statistical analysis

In a first step, the analysed parameters were tested using the Kolmogorov-Smirnov-test for Gaussian distribution. As the data were normally distributed, it was then possible to compare them using the ANOVA model for repeated measurements (linear model). This model is robust against deviations from the Gaussian distribution. Statistical calculations and analyses were performed using the SPSS statistical software programme.

4. Results

4.1 Data collected at halt

4.1.1 Loaded area

The average loaded area was 722.5 (± 35.9) cm². Statistically, the saddle used had no significant effect on the size of the loaded area (p-value: 0.105). Leathertree saddle B achieved a loaded area of 759.8 ± 40.9 cm², closely followed by leathertree saddle C (753.6 ± 38.9 cm²). The conventional dressage saddle achieved a mean value of 697.7 ± 36.5 cm² and leathertree saddle A loaded an area of 678.9 ± 43.1 cm².

Statistically relevant, however, was the effect of the side of the saddle (left vs. right side, p-value: 0.000). The average loaded area (all horses, all saddles) was significantly larger on the left side (760.3 ± 38.5 cm²) than it was on the right side (684.7 ± 33.7 cm²).

Also, as one would expect, there was a statistically significant difference between the data collected with (933.4 ± 35.1 cm²) and the data collected without rider (511.7 ± 38.4 cm²), which proves that the pressure mat worked during the trial (p-value: 0.000).

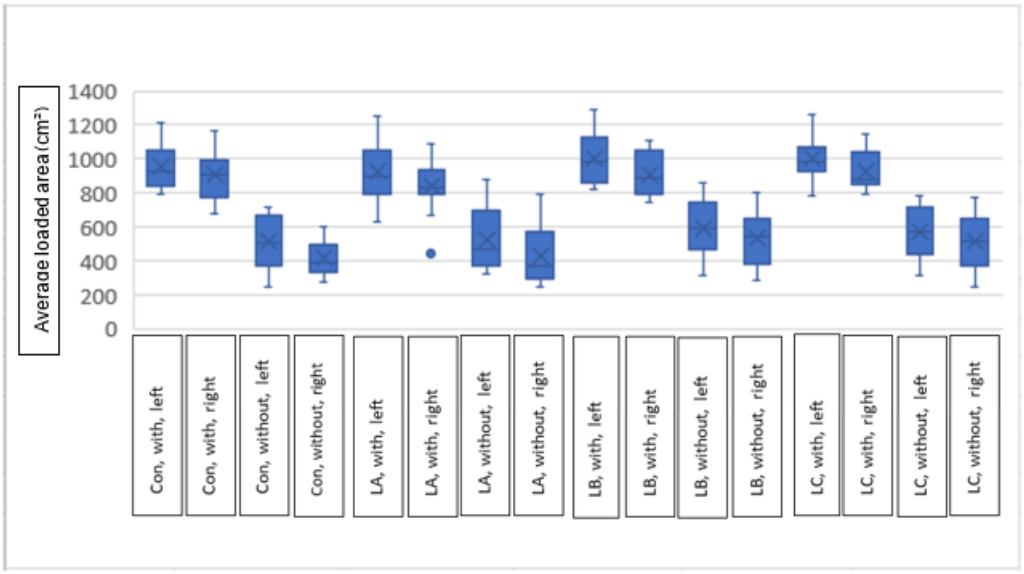


Fig. 14: Average loaded area (cm²) per saddle and per side with and without rider. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C, with = with rider, without = without rider

4.1.2 Area > 11 kPa

There was no statistically significant difference between the saddles included in the trial (p-value: 0.139). It made no difference whether the horse's conventional dressage saddle or one of the three leathertree dressage saddles was put on the horse. The average size of the area with pressures higher than 11 kPa was 225.4 ± 16.3 cm². Comparing the four tested saddles over all horses, leathertree saddle B loaded a total of 242.7 ± 17.7 cm² with pressures larger than 11 kPa, closely followed by leathertree saddle C (242.5 ± 18.8 cm²) and the conventional dressage saddle (216.3 ± 19.3 cm²). The saddle with the smallest high-pressure area was leathertree saddle A (199.9 ± 19.9 cm²).

As with the loaded area, there was a significant difference between the side of the saddle (left vs. right, p-value: 0.000). The average size of the area with pressures over 11 kPa (all horses, all saddles) was significantly larger on the left side (250.3 ± 16.2 cm²) than it was on the right side (200.4 ± 16.5 cm²). This was true for all of the tested saddles and also without rider.

Also, there was a statistically significant difference between the data collected with (366.0 ± 22.8 cm²) and the data collected without rider (84.7 ± 10.5 cm²), which proves that the pressure mat worked during the trial (p-value: 0.000).

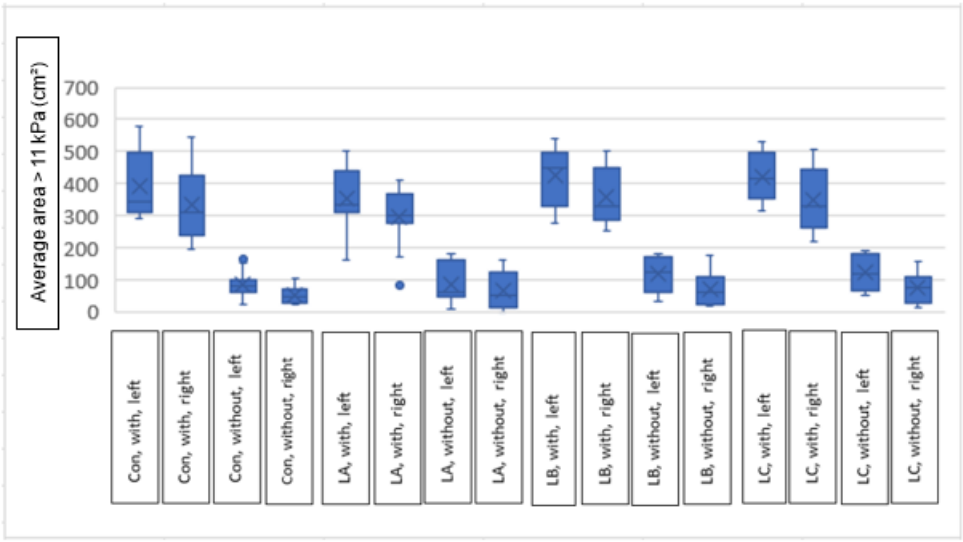


Fig. 15: Average size (cm²) of the area with pressures > 11 kPa per saddle and per side with and without rider. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C, with = with rider, without = without rider

4.1.3 Average pressure

There was no statistically significant difference (p-value: 0.249) between the tested saddles: Leathertree saddle C created an average pressure of 0.348 ± 0.024 N/cm², while leathertree saddle B and the conventional dressage saddle created average pressures of 0.351 ± 0.028 N/cm² and 0.318 ± 0.024 N/cm² respectively. Leathertree dressage saddle A landed at 0.294 ± 0.021 N/cm².

There was a statistically significant difference between the average pressures created on the left side (0.357 ± 0.024 N/cm²) of the saddle and the right side of the saddle (0.298 ± 0.021 N/cm²), the left side consistently putting higher pressures on the horseback (p-value: 0.000)

Also, there was a statistically significant difference between the data collected with (0.468 ± 0.028 N/cm²) and the data collected without rider (0.188 ± 0.018 N/cm²), which proves that the pressure mat worked during the trial (p-value: 0.000)

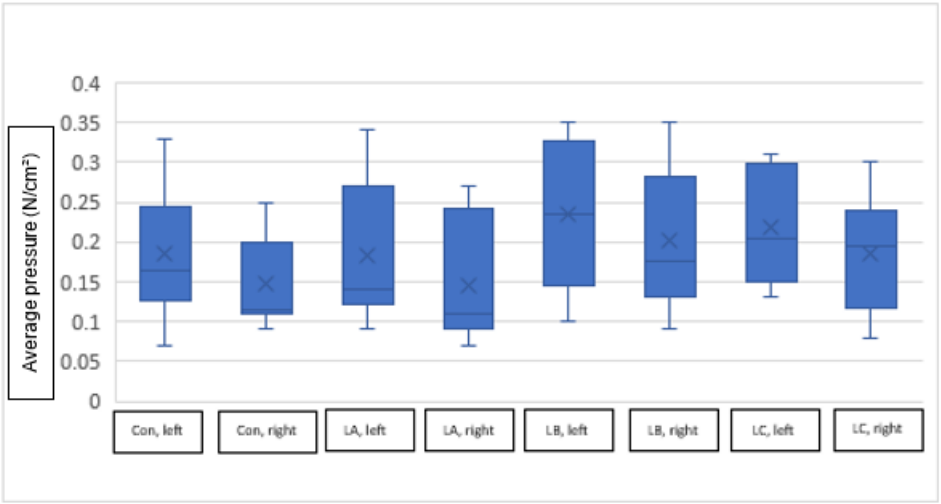


Fig. 16: Average pressure (N/cm²) per saddle and per side without rider. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C

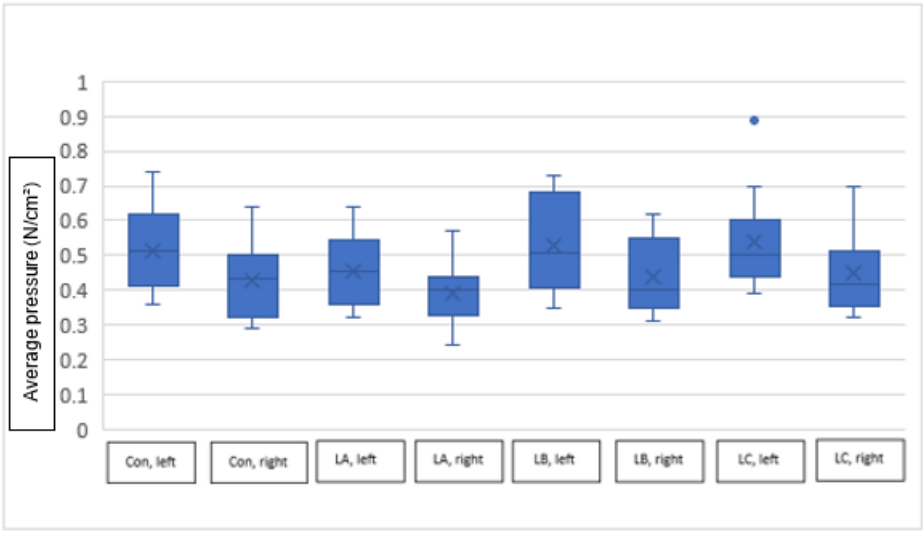


Fig. 17: Average pressure (N/cm²) per saddle and per side with rider. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C

4.1.4 Maximum pressure

The average maximum pressure exerted by the saddles in this trial was 3.5 ± 0,2 N/cm². The choice of saddle had no statistically significant effect on the pressure (p-value: 0.051): It did not matter whether the conventional dressage saddle or any of the leather tree dressage saddles was used. However, one considerable difference (p-value: 0.019) could be noted between the average maximum pressures created by two of the saddles: the conventional treed dressage saddle (3.9 ± 0.3 N/cm²) and the leathertree dressage saddle A (3.0 ± 0.2 N/cm²).

Again, there was a statistically significant difference between the maximum pressures measured under the different sides of the saddles (left vs. right, p-value: 0.001) as well with and without rider (p-value: 0.000), the latter serving to show that the pressure mat worked during data collection.

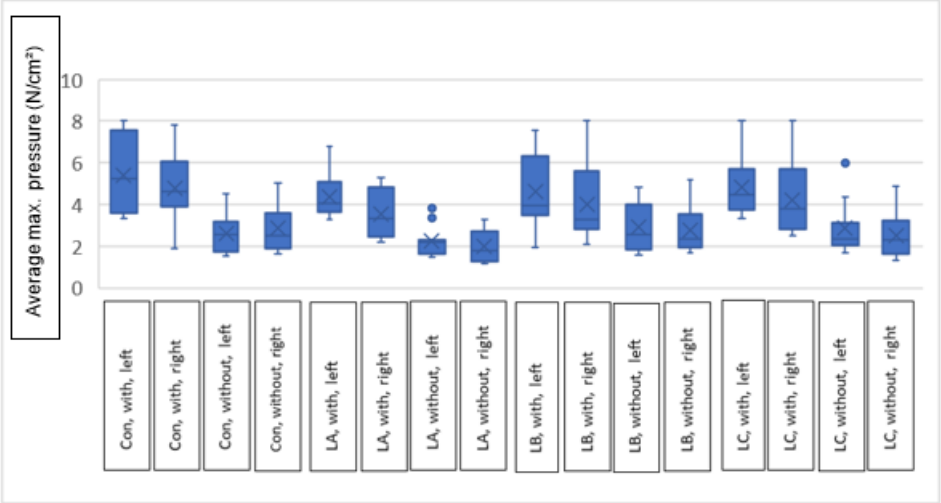


Fig. 18: Average maximum pressure (N/cm²) per saddle and per side with and without rider. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C, with = with rider, without = without rider

4.2 Data collected at trot

4.2.1 Average pressure

The average pressure exerted by the tested saddles was 0.504 ± 0.024 N/cm². This number includes all saddles used in the trial. Comparing the four tested saddles over all horses, the saddle used had no statistically significant effect on the average pressure (p-value: 0.792). Leathertree dressage saddle B created an average pressure of 0.512 ± 0.025 N/cm² while leathertree dressage saddle C put an average pressure of 0.509 ± 0.024 N/cm² on the horseback. Leathertree dressage saddle A and the conventional dressage saddle achieved mean values of 0.502 ± 0.024 N/cm² and 0.492 ± 0.029 N/cm² respectively.

The side of the saddle, on the other hand, did have a significant influence on the average pressure exerted on the horseback (p-value: 0.000): on the left side, the average pressure measured over all saddles and horses was 0.556 ± 0.026 N/cm², while on the right side of the saddle, the average pressure was 0.452 ± 0.023 N/cm². This finding was consistent across all saddles (see table 2): each of the tested saddles (Con, LA, LB, LC) put more average pressure on the left side of the horseback than it did on the right.

Tab. 2: Average pressure at trot in N/cm² - Combined effects of tested saddle and saddle side. Con = Conventional saddle, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C

	Average (SD)	Side	Average (per side)	SD (per side)
Con	0.492 (0.029)	left	0.536	0.031
		right	0.444	0.028
LA	0.502 (0.024)	left	0.557	0.027
		right	0.448	0.022
LB	0.512 (0.025)	left	0.571	0.028
		right	0.453	0.023
LC	0.509 (0.024)	left	0.555	0.025
		right	0.464	0.024

4.2.2 Maximum pressure

The average maximum pressure applied by the tested saddles was 4.5 ± 0.2 N/cm². This number includes all saddles used in the trial. There was, again, no statistically significant difference between the tested saddles (p-value: 0.642). The conventional dressage saddle exerted an average maximum pressure of 4.4 ± 0.2 N/cm², while leathertree dressage saddles A, B and C applied pressures of 4.5 ± 0,2 N/cm², 4.4 ± 0.2 N/cm² and 4.6 ± 0.2 N/cm² respectively. Therefore, regarding the average maximum pressure, it made no difference which saddle was used for the exercises.

In contrast to that, the side of the saddle (left vs. right) had a significant effect on the average maximal pressure (p-value: 0.000). The average maximum pressure created on the left side was 4.9 ± 0.2 N/cm², while on the right side it was lower with 4.1 ± 0.1 N/cm²). As can be seen from figure 17, this finding was consistent across all saddles, as each of the tested saddles (Con, LA, LB, LC) put more average maximal pressure on the left side of the horseback than it did on the right.

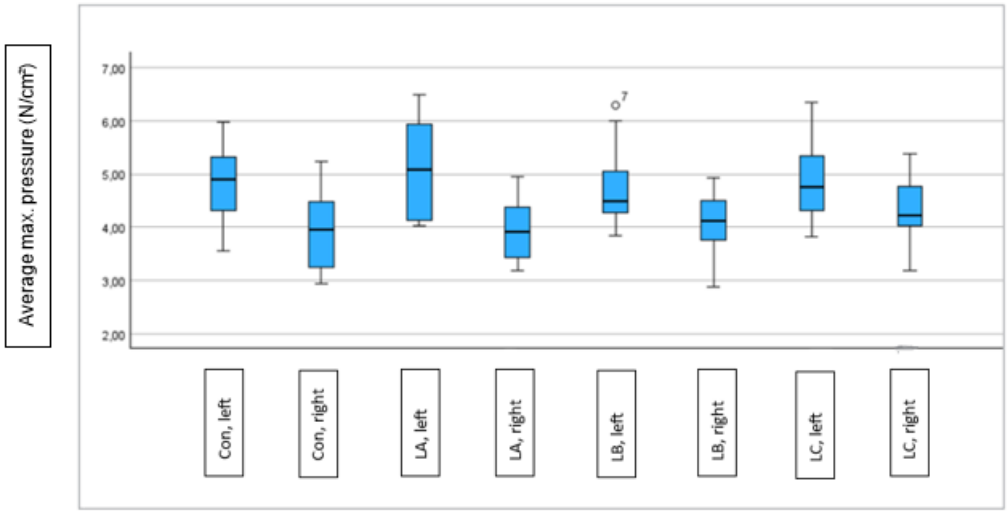


Fig. 19: Average maximum pressure (N/cm²) per saddle and per side at trot. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C

4.2.3 Center of pressure (COP)

The COP has been described as the center around which most of the pressure reaching the horseback is distributed (57). Better yet, one could say that it represents the point on a surface where the total sum of pressure or force is applied. In other words, it is the average location of all the forces exerted by the body on a supporting surface. Another interesting aspect about it is its range of motion, which is defined as the difference between the maximal and minimal COP coordinates and can thus be tracked both in the craniocaudal (anteroposterior) and in the laterolateral direction.

The statistical analysis of the collected data showed that the choice of saddle (p-value: 0.005), the side of the saddle (left vs. right, p-value: 0.004) and the direction (craniocaudal vs. laterolateral, p-value: 0.000) had a significant influence on the position of the center of pressure.

The largest average distance was covered by the conventional dressage saddle (286.5 ± 7.2 mm), followed by leathertree saddle C (270.2 ± 10.1 mm) and leather tree saddle A (249.6 ± 11.9 mm). Leather tree saddle B offered the highest degree of stability to the rider (246.8 ± 9.9 mm). While there was no statistically relevant difference between the three tested leathertree dressage saddles, both leathertree saddle A and leathertree saddle B showed a significantly

more compact pattern than the conventional dressage saddle (p-value: 0.025 and 0.002 respectively).

The excursion of the COP was larger on the left side of the saddle (mean value of 277.1 ± 6.8 mm) than it was on the right side (mean value of 249.4 ± 10.9 mm) and larger in the anteroposterior direction (mean excursion of 329.1 ± 10.9 mm) than in the laterolateral direction (mean excursion of 197.4 ± 8.3 mm). Fig. 18 and fig. 19 show the laterolateral as well as the craniocaudal excursion of the center of pressure per saddle and side at trot.

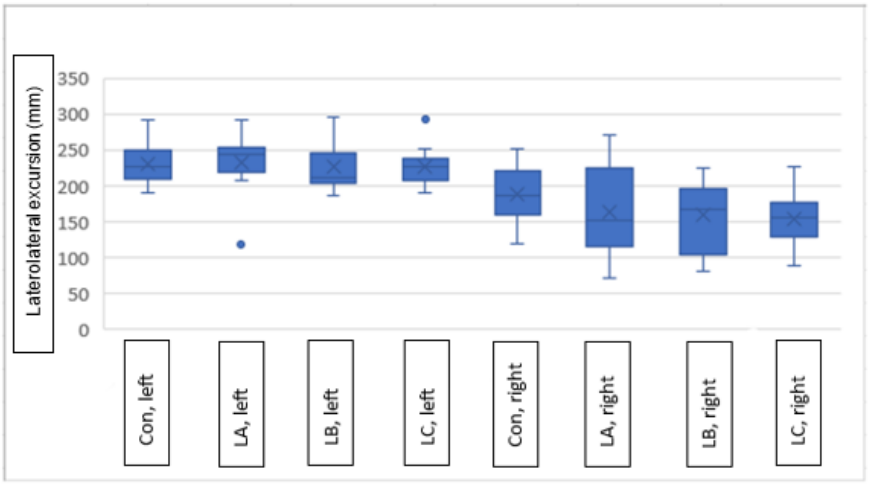


Fig. 20: Laterolateral excursion (mm) of the COP per saddle and side at trot. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C

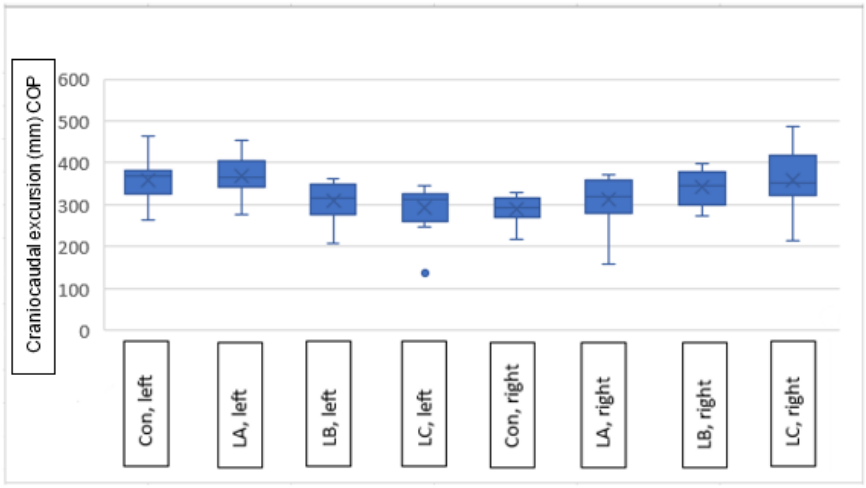


Fig. 21: Craniocaudal excursion (mm) of the COP per saddle and side at trot. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C

For more information on the performance of the single saddles per horse, please refer to the annex.

5. Discussion

5.1 Horses

For animal welfare reasons, only healthy horses were used for this study. This made also sense from a data point of view, as the pressure mat cannot distinguish between the influence of the rider, the saddle or the movements of the horse (17). If horses are sound, their thoracolumbar movements are symmetrical (11), which is a good starting point if we want to investigate the way pressures and forces are distributed by a saddle. It is well-documented that horses with hindlimb lameness and back pain alter the way force is distributed (58) and that ridden exercise can intensify both fore- and hindlimb lameness and is even apt to create hindlimb lameness in horses that suffer from backpain (9). Against this background specifically, only the use of non-lame horses can ensure that the data collected are reliable. Additionally, to avoid the misleading appearance of lameness during circles (50), measurments were conducted on straight lines only.

In order to find the 12 horses that were intended for this project, it was necessary to review more than 20 horses. It is not clear what degree of asymmetry is clinically relevant (51). For the purpose of this study, horses were considered free from lameness if they showed deviations from symmetry of *a)* ≤ 16 mm *and b)* ≤ 20% (i.e. at least 50% of all collected strides must not exceed 20% asymmetry (55)) according to the EquiGait analysis. Some of the horses initially considered for the study did not meet these criteria and were thus excluded. Some of the horses presented had, however, only narrowly missed the criteria set for the EquiGait examination. Given the potential limitations of automated gait analysis systems (50,51,53), trot-up videos of those horses were reviewed by a specialist in equine orthopaedics to provide a second opinion. Upon review of the videos, the specialist deemed some of the horses fit to participate, resulting in the final inclusion of 12 horses as intended at the beginning of the project.

5.2 Pressure mat

While there have been studies relating to user friendliness and repeatability (39–41) for other pressure mats, no such research yet exists for the *medilogic*® system. Subjectively speaking, however, no issues with repeatability or accuracy were noticed in the course of the data collection.

Also, there exists no data as to how often the *medilogic*® pressure mat should be calibrated or re-started so as to ensure trustworthy performance. In the case of the present study, the pressure mat was re-started at the beginning of each day of data collection, as earlier research had suggested for the use of the *Pliance* system (41).

Regarding material flexibility, however, some issues with horses of a certain body type were noticed. For horses with pronounced withers, it was more difficult to place the pressure mat in a way that ensured that the mat (and therefore the sensors) would not come into contact with the spinal column in the area of the withers. In that case, some of the pressure registered would come from contact with the horse's spine and not be produced by the saddles placed on the back. Luckily, this issue was identified during the phase in which the horses were made familiar with the equipment and therefore well before the actual measurements. Also, it concerned only two horses, both of which were anyway excluded from the study as they did not pass the lameness examination. However, back shape and the flexibility of the measuring device used should be considered when planning future projects as horse and pressure mat must be compatible so as to ensure realistic pressure measurements.

The biggest material-related problem detected in the course of the project was the way the embedded sensors register pressure applied to them. Some of the earlier research done considered the force exerted on the horseback an important variable to determine saddle fit (14,59). Therefore, the average force applied to all active sensors was calculated. This was done by multiplying the loaded area by the sum of all sensors active at that time and dividing the result by the product of sensor size and gravitation acceleration *g* (9.81 m/s²).

$$\frac{\textit{Loaded area} * \textit{sum of all sensors active}}{10.33\ cm^2 * g}$$

The numbers received for the overall force, however, were suspiciously low (14): they were even lower than the rider's body weight even though the horse was not moving. It was then realised that the sensors measure only direct contact pressures and do not account for pressure distribution across the sensor area (10.33 cm² according to the manufacturer). Consequently, calculations based on sensor size were problematic. This meant that not only the values calculated for the overall force, but also the values for the loaded area and the area with pressures higher than 11 kPa had to be considered with caution. They show tendencies

rather than precise measurements, which was accepted for the static measurements. These calculations were, however, altogether omitted for the data collected at trot.

5.3 Discussion of the data collected at halt

5.3.1 Loaded area

The saddle used had no influence on the size of the average loaded area, which was 722.5 ± 35.9 cm² (leathertree saddle B 759.8 ± 40.9 cm², leathertree saddle C 753.6 ± 38.9cm², conventional dressage saddle 697.7 ± 36.5 cm², leathertree saddle A 678.9 ± 43.1 cm²). Thus, it was considerably smaller than what earlier research had found. Belock et al. (2) had determined an average contact area of 1340.0 ± 66 cm² for the conventional dressage saddle and 1153.0 ± 94 cm² for the tested treeless saddle (significant difference). Clayton et al. (4) had found an average loaded area of 1208.0 ± 150 cm² for the conventional saddle and a loaded area of 1115.0 ± 160 cm² for the treeless saddle (difference not significant). Ramseier et al. (3) had determined values similar to those of Clayton et al. for the dressage-style saddle and the saddle cushion investigated both at walk and tölt.

The fact that the values received in the present study were lower was no surprise as the sensors in the pressure mat measure only direct contact pressures and do not account for pressure distribution across the sensor area (see chapter 5.2). Therefore, the values for the contact area can only reflect trends and no absolutes. These trends, however, show a different picture from the findings of Belock et al. and Clayton et al. (2,4), where the performance of the conventional saddle was superior to the performance of the treeless saddle, in the case of the former even significantly so (p-value < 0.05). In the present study, the choice of saddle made no difference, which means that the proposed *Hypothesis a)* is not supported by the collected data.

5.3.2 Area > 11 kPa

Also, as opposed to the results of previous research (2,4), the present study found no statistically significant influence of the saddle used on the size of the area where pressures higher than 11 kPa registered. In the study performed by Belock et al. (2), the area with mean pressures > 1.1 N/cm² was significantly larger in the case of the treeless saddle (124 ± 48 cm²)

than it was in the case of the conventional saddle (10 ± 15 cm²). The study performed by Clayton et al. in 2014 (4) showed similar results (treeless saddle: 286.9 ± 39.7 cm², conventional saddle: 28.3 ± 45.9 cm²) and equally found a significant difference between the saddles reviewed. The four saddles tested in the present study, on the other hand, delivered very similar results, which in terms of magnitude came closer to the results obtained by Clayton et al. than they did to the results Belock et al. received. Given that there was no statistically relevant difference between the four saddles, the proposed *Hypothesis d)* was not backed up by the collected data.

5.3.3 Average pressure

There was no statistically relevant difference between the four tested saddles with regard to the average pressure. Consequently, proposed *Hypothesis b)* was not supported by the data.

5.3.4 Maximum pressure

The choice of saddle had no statically relevant effect on the average maximum pressure applied. The only statistically significant difference (p-value: 0.019) was to be found between the conventional dressage saddle (39.0 ± 3.0 kPa) and leathertree dressage saddle A (30.0 ± 2.0 kPa). Contrary to what had been expected at the beginning of the project, the conventional dressage saddle did not outperform the leathertree dressage saddles. Leathertree dressage saddle A put a lower average maximum pressure on the horseback. Other than that, there was no statistically relevant difference between the saddles.

If we compare the findings of the present study to the data collected by Belock et al. (2), our values are higher even though Belock et al. collected their data at a faster gait (sitting trot) and even though they did not calculate the average maximum pressure but rather the maximal pressure on any sensor at any time. In a similar fashion, Clayton et al. (4) measured a maximal pressure of 29.4 ± 7.0 kPa for the conventional saddle and 42.8 ± 7.6 kPa for the treeless saddle (maximal pressure on any sensor; significant difference), which comes closer to the values determined for the four saddles that we tested. All in all, the proposed *Hypothesis c)* was not supported by the data collected in the course of the present study.

5.3.5 Summary analysis of the data collected at halt

Looking back at the five working hypotheses formulated at the beginning of the project (see chapter 1.1), we can determine that none of the hypotheses was supported by the findings. There were no statistically significant differences between the saddles.

There was, however, a significant difference between the values determined for the different sides of the saddle. For all of the tested parameters (loaded area, area larger than 11 kPa, average and maximum pressure), the values achieved were higher on the left than they were on the right side of the saddle. This was also true for the loaded area and the area where pressures larger than 11 kPa registered without rider. Especially in the case of the area > 11 kPa it was surprising to see pressures that high without a rider in the saddle. The same trend, on the other hand, could not be witnessed for the average maximum pressure, where the maximum pressure reached without a rider was higher on the right side for all saddles but leathertree saddle B.

No horse or rider is fully symmetrical on both sides (50), and as the pressure mat cannot distinguish between the influence of the rider, the saddle or the movements of the horse (17), this difference could theoretically be a result of a crookedness of both horse and rider. Additionally, it could be caused by an asymmetry of the saddle. Given, however, the consistency with which this phenomenon could be witnessed and the variety of horses and saddles used in the study, the most likely answer is that it was caused by an asymmetry of the rider. Interestingly enough, earlier research has found similar results (16).

Also, there was a statistically significant difference between the data collected with and the data collected without rider. This proves that the pressure mat worked during the trial. Due to the weight of the saddle and the traction coming from the tightened girth, the values obtained during the measurements without rider were larger than zero (39).

Previous research has demonstrated that a certain amount of pressure can cause backpain or tissue damage (18,23,25). Therefore, it was interesting to consider the average and the maximum pressures under the saddles included in this study.

None of the average pressures determined was apt to create backpain with the horses used in the trial. According to the findings of Nyikos et al. (18), that is the case with mean pressures larger than 13.2 kPa under the front part and mean pressures larger than 10.0 kPa under the

hind part of the saddle. Furthermore, the values in the present trial lay well below the thresholds established by research done in the human field (23,25).

Regarding the maximum pressures, however, three of the four tested saddles exceeded the threshold Nyikos et al. (18) had established for backpain (maximum pressures > 34.5 kPa under the front part of the saddle and > 31.0 kPa under the hind part of the saddle). Leathertree dressage saddle A was the only saddle to produce maximum pressures that were lower than 31.0 kPa.

A limitation of the present study was that it did not determine separate values for the front and hind part of the saddle area. This rendered categorisation according to the system suggested by Nyikos et al. difficult. As not all regions of the horseback tolerate the same levels of pressure, future projects should make sure to include this information.

5.4 Discussion of the data collected at trot

Given the way that the sensors in the pressure mat measure the pressure that applies to them (see chapter 5.2) the calculations of the loaded area and the area with pressures larger than 11 kilopascals were altogether omitted for the data collected at trot. Therefore, only the average and maximum pressures were examined. Additionally, the range of motion (ROM) of the rider's center of pressure (COP) at trot was included into the scope.

5.4.1 Average pressure

The choice of saddle had no statistically significant effect on the average pressure at trot. Consequently, proposed *Hypothesis b)* was not supported by the data. The average pressure under the tested saddles was 5.04 ± 0.24 kPa. Leathertree dressage saddle B created an average pressure of 5.12 ± 0.25 kPa, leathertree dressage saddle C put an average pressure of 5.09 ± 0.24 kPa on the horseback, leathertree dressage saddle A and the conventional dressage saddle achieved mean values of 5.02 ± 0.24 kPa and 4.92 ± 0.29 kPa respectively.

Belock et al. (2) found mean pressures of 6.3 ± 0.2 kPa under the conventional and 6.9 ± 0.4 kPa under the treeless *Ansur* saddle at sitting trot, which is slightly higher than the average pressures in the present study, but lower than the pressures found by Clayton et al. (4) which determined pressures of 7.0 ± 0.4 kPa for the conventional and 8.6 ± 0.3 kPa for the treeless

Ansur saddle. In a study by Roost et al. (16), where four riders of equal skill but different size rode a total of six horses, mean pressures of 5.1 ± 1.5 kPa and mean maximum pressures of 12.1 ± 3.4 kPa were measured at trot. Interestingly enough, the roughly same values were received for canter, which was not possible for all horses under the two heaviest riders. Ramseier et al. (3) determined average pressures of 8.8 ± 0.4 for the dressage-style saddle as well as 8.1 ± 0.6 for the treeless saddle cushion tested. It should, however, be mentioned that Ramseier et al. (3) collected these data at tölt, which normally has no suspension phase (60) and might thus deliver results that differ from what would be found at trot.

5.4.2 Maximum pressure

Regarding the average maximum pressure, there was again no statistically significant difference between the four tested saddles. The proposed *Hypothesis c)* was not supported by the data collected in the course of the present study. The conventional dressage saddle exerted an average maximum pressure of 44.0 ± 2.0 kPa, while leathertree dressage saddles A, B and C applied pressures of 45.0 ± 2.0 kPa, 44.0 ± 2.0 kPa and 46.0 ± 2.0 kPa respectively. Compared to the findings of Belock et al. (2) who determined a maximum pressure of 20.7 ± 4.4 kPa for the conventional saddle and a maximum pressure of 29.4 ± 3.8 kPa for the treeless saddle, the values of the present study are altogether higher. Closer to the values of the four saddles tested but still lower are the maximum pressures identified by Clayton et al. ((4); 29.4 ± 7.0 kPa for the conventional and 42.8 ± 7.6 kPa for the treeless saddle).

The fact that the values found in the present study range higher than those in the earlier studies could potentially be due to the higher variability of the horses used: while both the study by Belock et al. and Clayton et al. exclusively used Arabian horses, the horse population of the present study was more diverse. Of the twelve horses, eight were Iberian-bred and two were German-bred. Both Iberian and German horses persue breeding objectives that largely differ from that of the Arabian horse, which are often bred for races or endurance competitions rather than spectacular movements and collection. It is known that horses with bouncy movements receive a higher inertial loading of the horseback than horses with rather flat movements (28). This is due to the gravitational forces coming from the rider, which are higher in horses with more exalted movements (28). This could potentially explain the higher values received in the present study. After all, Nyikos et al. (18) found average maximum pressures very similar to

the ones in the present study while also working with horses of different breeds, purpose and training level.

5.4.3 Center of pressure

The COP was the last variable that was contemplated at trot. The statistical analysis of the data has shown that not only the choice of the saddle, but also the side of the saddle and the plane had a significant influence on the COP.

The excursion of the COP was larger on the left side (mean value of 277.1 ± 6.8 mm over all saddles) than it was on the right (mean value of 249.4 ± 10.9 mm over all saddles), which was no surprise given that the situation had been similar for all the other tested parameters. It can be speculated that this is, again, because of rider asymmetry.

Furthermore, the ROM of the COP was larger in the anteroposterior direction than in the laterolateral direction. This was equally unsurprising as the horse's body witnesses the largest accelerations through the effects of the braking and propulsive longitudinal ground reaction forces (57). The ROM of the rider's COP is furthermore influenced by speed (57) and ground properties and is larger when the ridden exercise is performed on soft ground than it is when it is performed on hard surfaces (61).

Comparison of the range of motion of the four tested saddles' COP has shown that the largest average distance was covered by the conventional dressage saddle (286.5 ± 7.2 mm), followed by leathertree dressage saddle C (270.2 ± 10.1 mm) and leathertree saddle A (249.6 ± 11.9 mm). Leathertree saddle B displayed the smallest ROM (246.8 ± mm) and therefore offered the highest degree of stability to the rider (57).

Research by Clayton et al. has shown that the ROM of the rider's COP is smaller if the saddle used allows for closer contact between the rider's legs and the horse and that it increases with the speed at which the horse-rider team moves (57). In the present study, the velocity of the trot has not been objectively controlled and might have differed between horses. Subjectively, it was stable on an inter-horse-level. While this should therefore not be the reason for the significant difference between the single saddles, it would be advisable to control the velocity in future research projects. It is furthermore possible that the tested leathertree dressage saddles allowed for closer contact between the rider's legs and the horse. However, verifying this hypothesis would require further investigations. Interestingly, the values Clayton et al. (57)

received even at extended trot (120.9 ± 21.7 mm for the conventional saddle and 95.0 ± 13.9 mm for the flapless saddle) were drastically lower than the values determined in the present study. Given that their data collection was also carried out on the soft ground of a dressage arena, ground conditions cannot serve to explain why their values were considerably lower (61).

5.4.4 Summary analysis of the data collected at trot

The data collected at trot did not support *Hypotheses b)* and *c)*. While the average pressures exerted by the four tested saddles were lower than the thresholds defined by Nyikos et al. and thus unlikely to cause backpain in the horses (18), they lay above the limits defined by Holloway et Chang et al. (23,25). Regarding the maximum pressures at trot, all of the aforementioned thresholds were exceeded. This stresses the importance of the naturally occuring loading and unloading of the horseback in the course of the movement cycle and should give rise to keeping training sessions as short as possible (4).

For both the average and the maximum pressures exerted at trot, it became apparent that there was a statistically significant difference between the two sides of the saddle: on the left side, the values were constantly higher than on the right side. As discussed for the data collected at halt, it is hard to defintely disentagle the effects which could cause such results (natural or pathological crookedness of horse and/or rider, unequal padding of saddle cushions or crookedness of saddle, assymetry of the dorsal muscles of the horse, lameness, to name only a few). Doing this would require further research and would go well beyond the scope of the present thesis. Given, however, the consistency with which this observation was made, the most likely scenario seems to be a certain crookedness of the rider.

Of all the tested variables, the COP was the only one where there were distinct differences between the four saddles. The decision to analyse it came only in the course of the project, therefore unfortunately no provisions to ensure an ideal test setting were made beforehand. These should have preferably included collecting the data at a controlled speed and on surfaces as homogeneous as possible. Furthermore, it would have been worthwhile to take exact measurements of the saddle flaps in order to be able to verify whether any differences in results can be explained by the closeness of contact between rider’s legs and the horse.

6. Conclusion and outlook

As stated above, none of the hypotheses formulated prior to the collection of the data could be verified. Even though the conventional saddles used in the trial had mostly been semi-custom-made or even custom-made saddles for the horses they belonged to and had only recently been checked by a saddler, they did not outperform the three leathertree dressage saddles that were chosen for the project. Whether or not other models or brands of saddles would deliver comparable results is of course subject to further research; however, the fact that the saddler involved in the project had minutes rather than hours to adapt the leathertree saddles to the horses – the number of saddles to be tested and exercises to be performed making the undertaking a complex one – gives cause to hope that leathertree saddles could be an affordable as well as feasible way of equipping many horse-rider-teams with saddles that fit.

The current study had some limitations, among them the flexibility of the pressure mat and the way the embedded sensors register pressure applied to them (see chapter 5.2). Also, as with other pressure measuring devices (40,62), the mat only registers those forces that apply perpendicularly to it, so no shear forces are considered (16). As already mentioned, it would be interesting to repeat the measurements with a pressure mat that allows more exact calculations of the surface areas and the forces that apply to the horseback. For those measurements, speed should be controlled so that the data collected can be ideally compared with regard to pressure and force (15,16). Also, future research should make sure to divide the saddle area into zones (18) so as to be able to make statements about the amount of pressure in certain areas under the saddle. In the future, so-called smart textiles, which are currently more and more developed and studied, could be designed so as to facilitate pressure measurements or be even integrated into the horse's equipment (63).

Hindsight is easier than foresight – this saying holds true also for the project at hand. In retrospect, many more aspects could have been included. These would have allowed to gain further insights or answer research questions that have arisen in the course of the journey. For example, one could measure the thoracic width pre- and post-exercise as an indicator for saddle fit and desirable movement patterns especially under lightweight riders (16).

Also, it would be interesting to integrate behavioural scales which give hints as to how well horse welfare is protected during exercise under different saddles. In the course of the study, the subjective impression that many of the horses were more content under one of the leathertree dressage saddles than under their own conventional saddle was formed among

the ones actively participating in the realisation of the measurements. From a subjective standpoint, those horses seemed to move more freely from the shoulder and seemed to be more content and relaxed than under their own saddle. It would have therefore been interesting to use close-up videos as well as a scale system to analyse whether the horses showed signs of discomfort or pain at any point during the data collection. Especially at times like the present, where the use of horses in competition or even recreational sports is highly disputed (64), it seems more important than ever to ensure horse welfare. After all, the *Féderation Equestre Internationale* has not without reason included the concept of the "happy athlete" into their rules (65), and research should contribute to this notion by collecting not only hard, but also soft data wherever feasible and useful. Animal body language can give a lot of information about their welfare (66). Most of the existing pain scales refer to orthopaedic pain, post-surgery or colic pain (67,68), but there has been an effort to design ethograms to objectively document limb kinematics and behavioural patterns as markers of discomfort or pain (69,70). These could be used as a basis to create a scale that supports and expands similar projects in the future.

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9. Annex

Annex 1: Sample examination protocol

PROTOKOLL Datum_____

Projekt: „Under pressure: Beurteilung der Druckverhältnisse unter einem Dressursattel mit konventionellem Sattelbaum sowie unter drei Dressursätteln mit Ledersattelbaum."

Pferdename: _____

1. DOKUMENTATION:

- Name Eigentümer: _____
- Eigener Sattel (Modell, Hersteller): _____
- Tierhaltereinverständniserklärung unterzeichnet ☐
- Einwilligung Datenschutz unterzeichnet ☐

2. VORUNTERSUCHUNG

A) Nationale:

- Alter des Pferdes: _____
- Rasse: _____
- Geschlecht: _____
- Nutzung: _____

B) Abgekürzte allgemeine Untersuchung:

- **Atmung:** ____/min., kostoabdominaler Atemtypus, regelmäßig, ggr. vertieft ☐
  - Abweichender Befund: _____ ☐
- **Puls:** ____/min., kräftig, regelmäßig, gleichmäßig, A. gut gefüllt und gut gespannt ☐
  - Abweichender Befund: _____ ☐
- **Lidbindehaut:** blassrosa ☐
- **Maulschleimhaut:** blassrosa, keine Blutungen an Zungenunterfläche ☐
- **KFZ:** ____ sec.
- **IKT:** ____ Grad°

C) Abgekürzte orthopädische Untersuchung:

- **Gliedmaßenstellung von vorne:**
  - Regelmäßig gerade/weit/eng ☐
  - Bodenweit/bodeneng ☐
  - Carpus valgus/varus ☐
  - Abweichende Befunde: _____
- **Gliedmaßenstellung von hinten:**
  - Regelmäßig gerade/weit/eng ☐
  - Bodenweit/bodeneng ☐
  - Tarsus valgus/varus ☐
  - Abweichende Befunde: _____
- **Gliedmaßenstellung von der Seite:**
  - Regelmäßig und gerade ☐
  - VE: vorständig/rückständig ☐

- HE: unterständig/rückständig/säbelbeinig/stuhlbeinig ☐
- Abweichende Befunde: _____

- **Zehenstellung von vorne:**
  - Regelmäßig und gerade/weit/eng ☐
  - Zeheneng/zehenweit ☐

- **Zehenstellung seitlich:**
  - Regelmäßig ☐
  - Spitz/stumpf gewinkelt ☐
  - Abweichende Befunde: _____

- **Palpation von Huf und Zehe vorne und hinten:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen[1] Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Metacarpus:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Karpalgelenk:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Unterarm:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Oberarm, Schulter, Scapula:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Metatarsus**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Tarsalgelenk:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐

---

[1] „zugehörige Strukturen" meint stets alle Strukturen gemäß Baumgartner, W. Klinische Propädeutik der Haus- und Heimtiere, 8. Auflage

- Abweichende Befunde: _____

- **Palpation Unterschenkel:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Knie:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle zugehörigen Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Palpation Oberschenkel:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle untersuchten Strukturen o.B. ☐
  - Abweichende Befunde: _____
  -

- **Palpation Hüfte und Becken:**
  - Keine Schmerzhaftigkeit feststellbar ☐
  - Alle untersuchten Strukturen o.B. ☐
  - Abweichende Befunde: _____

- **Adspektion der Bewegung im Schritt auf gerader Linie:**
  - **Vorführbogen Vorderextremität:**
    - Vorführbögen auf der Linie ☐
    - Abweichende Befunde: _____
    - Lahmheit vorhanden: ☐
      - Stützbeinlahmheit (I-V): _____
      - Hangbeinlahmhiet (ggr.-hgr.): _____
      - Gemischte Lahmheit (ggr.-hgr.): _____
      - Scheinlahmheit: _____

- **Adspektion der Bewegung im Trab auf gerader Linie, 4x 30 m → EQUIGAIT plus Handyvideo:**
  - Bewegung ist symmetrisch (gemessene Abweichungen kleiner oder gleich 12mm) ☐

→ **Pferd kann gemäß den erhobenen Befunden an der Studie teilnehmen!** ☐
  - **Falls nein, Begründung:** _____

D) DRUCKMESSUNGEN mittels Medilogic® und VIDEOAUFNAHME (8 pro Modell):

- Korrektes Auflegen Druckmessmatte ☐
- Auflegen eigner Sattel (= Baumsattel) + Eskadronschabracke ☐
  - Pferd kurz aufwärmen ☐
  - Messung im Stand ohne Reiterin 30 sec. (Kommentar: Baumsattel Stand ohne Reiterin) ☐
  - Messung im Stand mit Reiterin 30 sec. (Kommentar Baumsattel Stand mit Reiterin) ☐
  - Messung im Schritt unter Reiterin 3 x 30 m (Kommentar: Baumsattel Schritt 1-3) ☐
  - Messung im ausgesessenen Trab unter Reiterin 3 x 30 m (Baumsattel Trab 1-3) ☐

➔ *Auflegen Lederbaumsättel in zufälliger Reihenfolge –> Jeweiliges Modell bitte ankreuzen u. Kontrolle Position Druckmessdecke vor Start der Messungen*

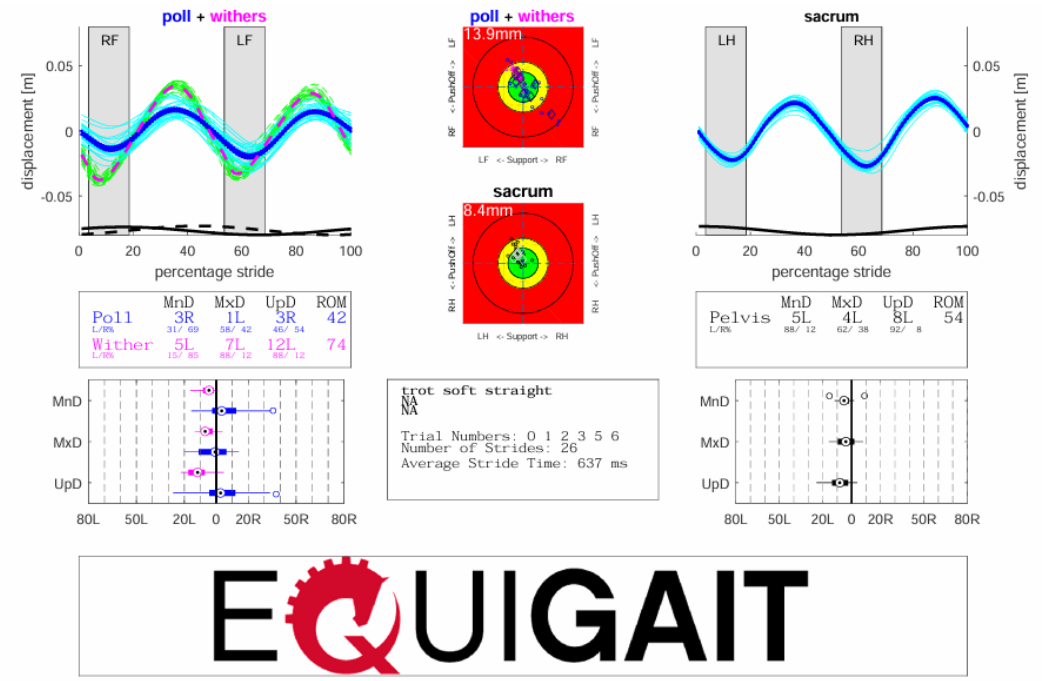
- Auflegen LEDERBAUMSATTEL 1 inkl. gepolsteter Grandeurschabracke (Polsterung: _____)
  - Modell „Viento" Firma CE-Sattelglück ☐
  - Modell „Event" Firma Sorenta Sattel ☐
  - Modell „Venice Spezial" Firma Hidalgo ☐
  - **Messungen:**
    - Im Stand ohne Reiterin 30 sec. (Komm.: Lederbaum, *Modellname*, Stand o. Reiterin) ☐
    - Messung im Stand mit Reiterin 30 sec. (Kommentar siehe oben, Stand m. R.) ☐
    - Messung im Schritt unter Reiterin 3 x 30 m (Kommentar siehe oben, Schritt 1-3) ☐
    - Messung im ausgesessenen Trab unter Reiterin 3 x 30 m (Kommentar s.o., Trab 1-3) ☐

- Auflegen LEDERBAUMSATTEL 2 inkl. gepolsterte Grandeurschabracke (Polsterung: _____)
  - Modell „Viento" Firma CE-Sattelglück ☐
  - Modell „Event" Firma Sorenta Sattel ☐
  - Modell „Venice Spezial" Firma Hidalgo ☐
  - **Messungen:**
    - Im Stand ohne Reiterin 30 sec. (Komm.: Lederbaum, *Modellname*, Stand o. Reiterin) ☐
    - Messung im Stand mit Reiterin 30 sec. (Kommentar siehe oben, Stand m. R.) ☐
    - Messung im Schritt unter Reiterin 3 x 30 m (Kommentar siehe oben, Schritt 1-3) ☐
    - Messung im ausgesessenen Trab unter Reiterin 3 x 30 m (Kommentar s.o., Trab 1-3) ☐

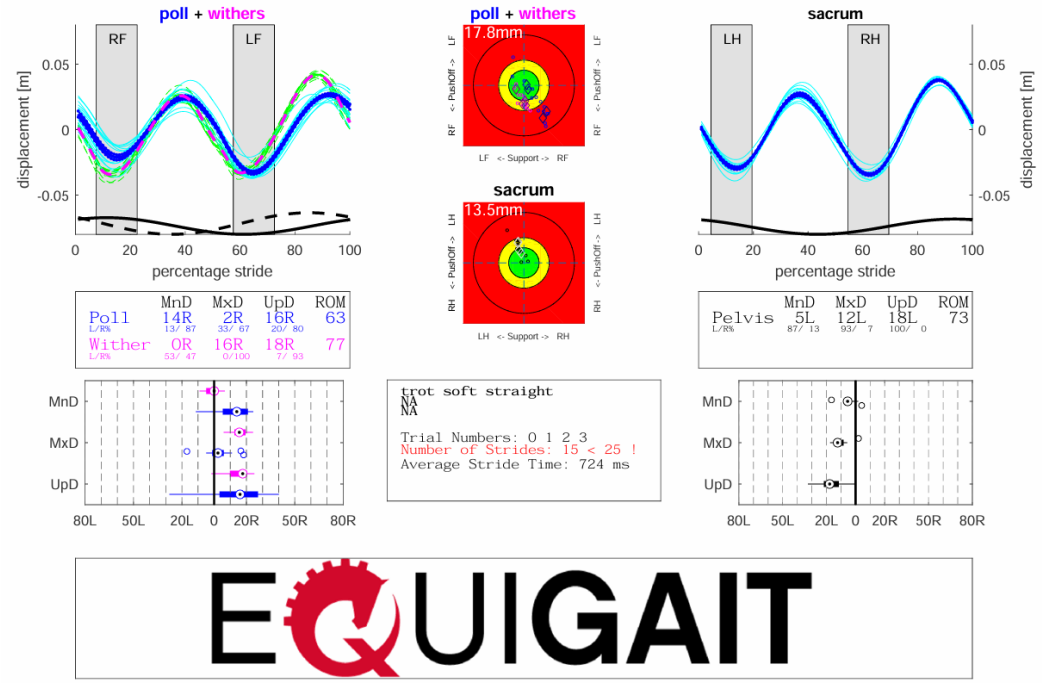
- Auflegen LEDERBAUMSATTEL 3 inkl. gepolsterte Grandeurschabracke (Polsterung: _____)
  - Modell „Viento" Firma CE-Sattelglück ☐
  - Modell „Event" Firma Sorenta Sattel ☐
  - Modell „Venice Spezial" Firma Hidalgo ☐
  - **Messungen:**
    - Im Stand ohne Reiterin 30 sec. (Komm.: Lederbaum, *Modellname*, Stand o. Reiterin) ☐
    - Messung im Stand mit Reiterin 30 sec. (Kommentar siehe oben, Stand m. R.) ☐
    - Messung im Schritt unter Reiterin 3 x 30 m (Kommentar siehe oben, Schritt 1-3) ☐
    - Messung im ausgesessenen Trab unter Reiterin 3 x 30 m (Kommentar s.o., Trab 1-3) ☐

Annex 2: EquiGait protocols per horse

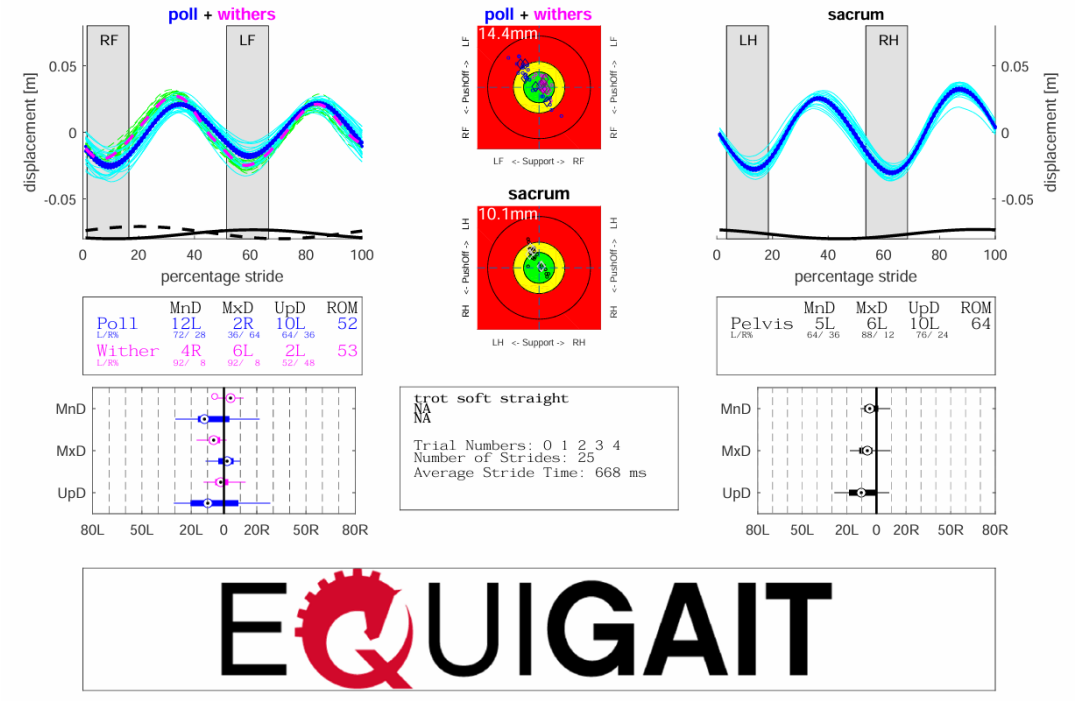
Horse1



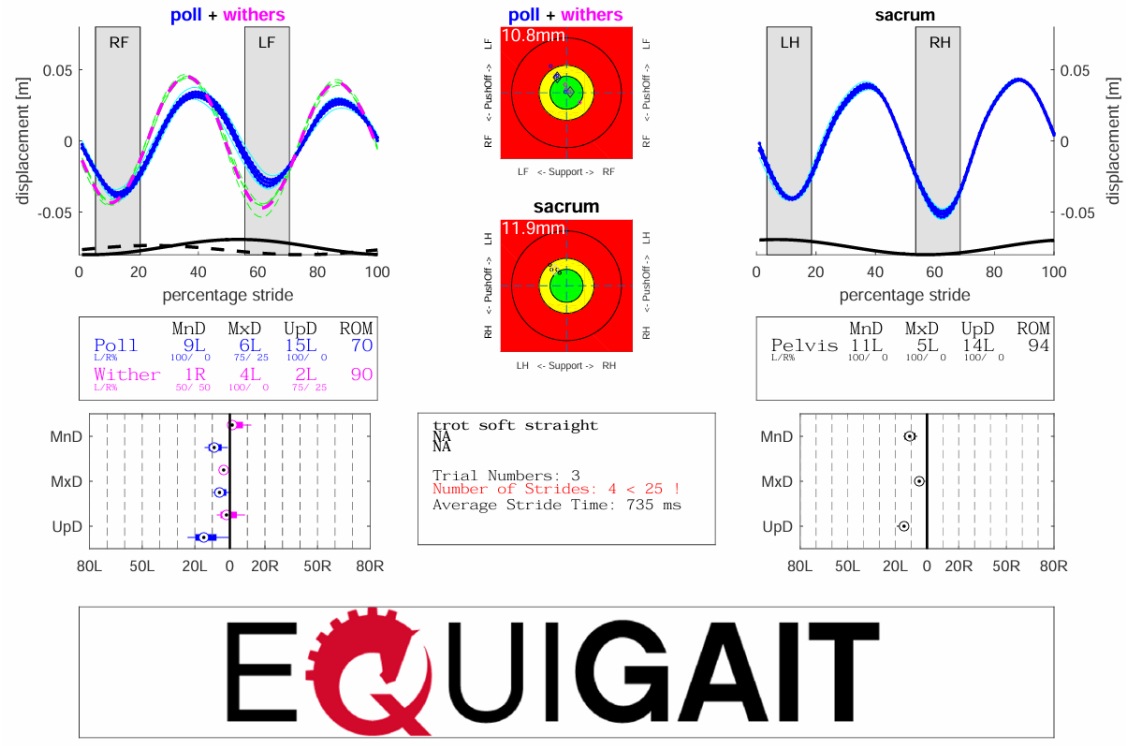
Horse 2



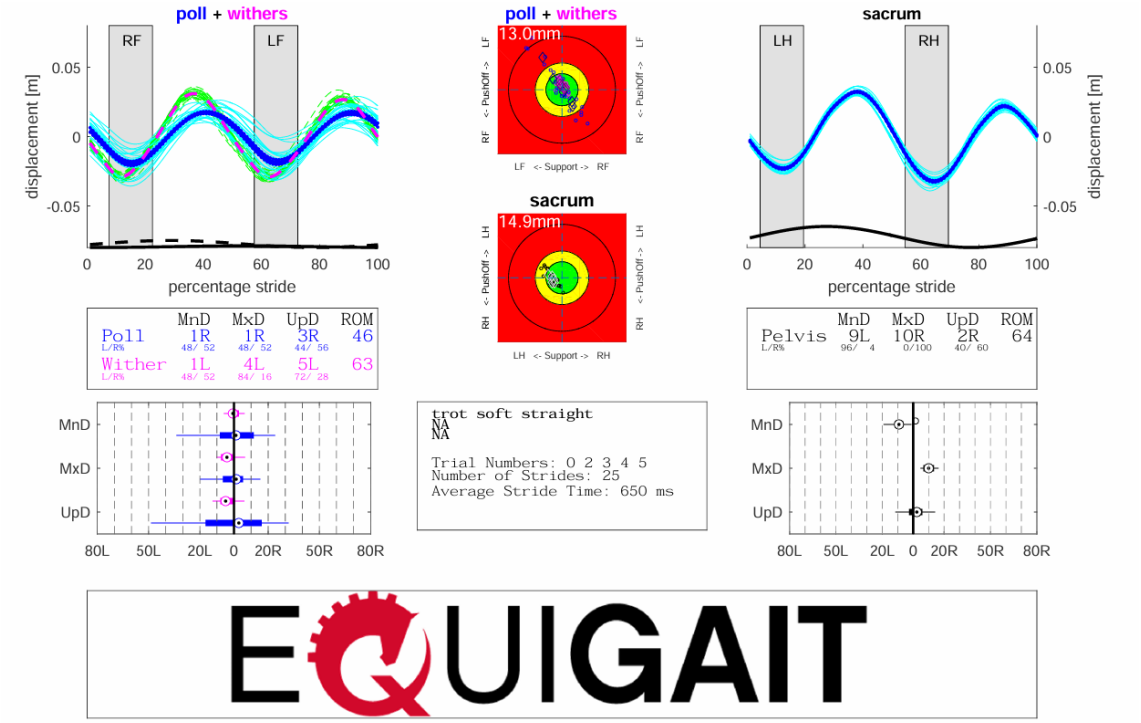
Horse 3



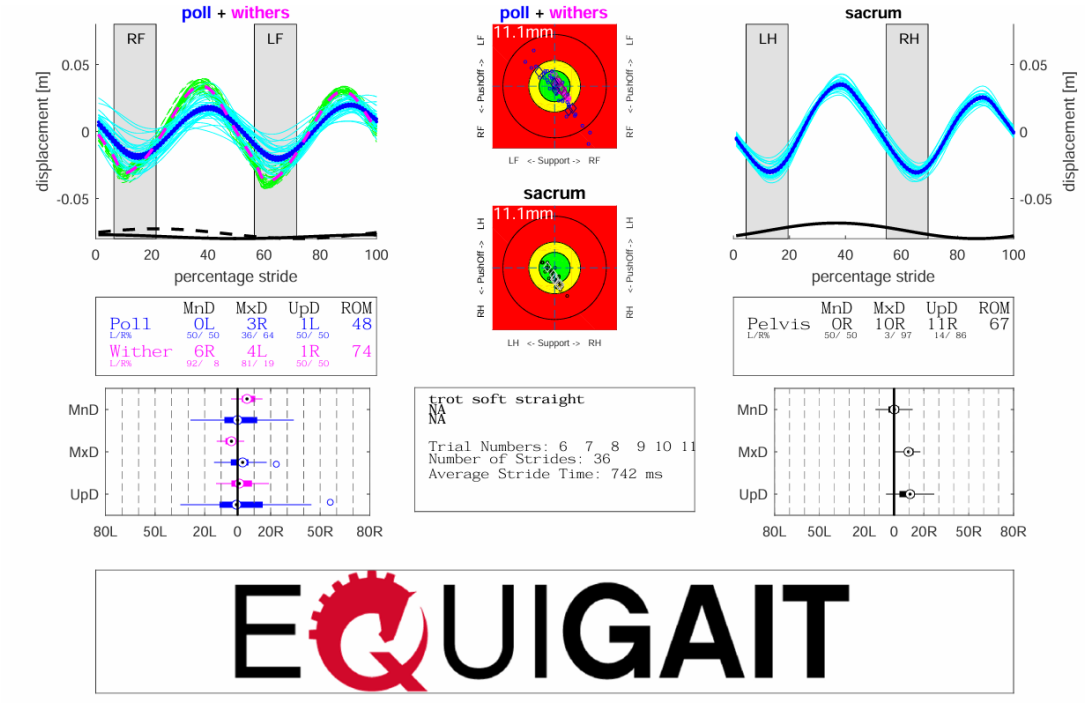
Horse 4



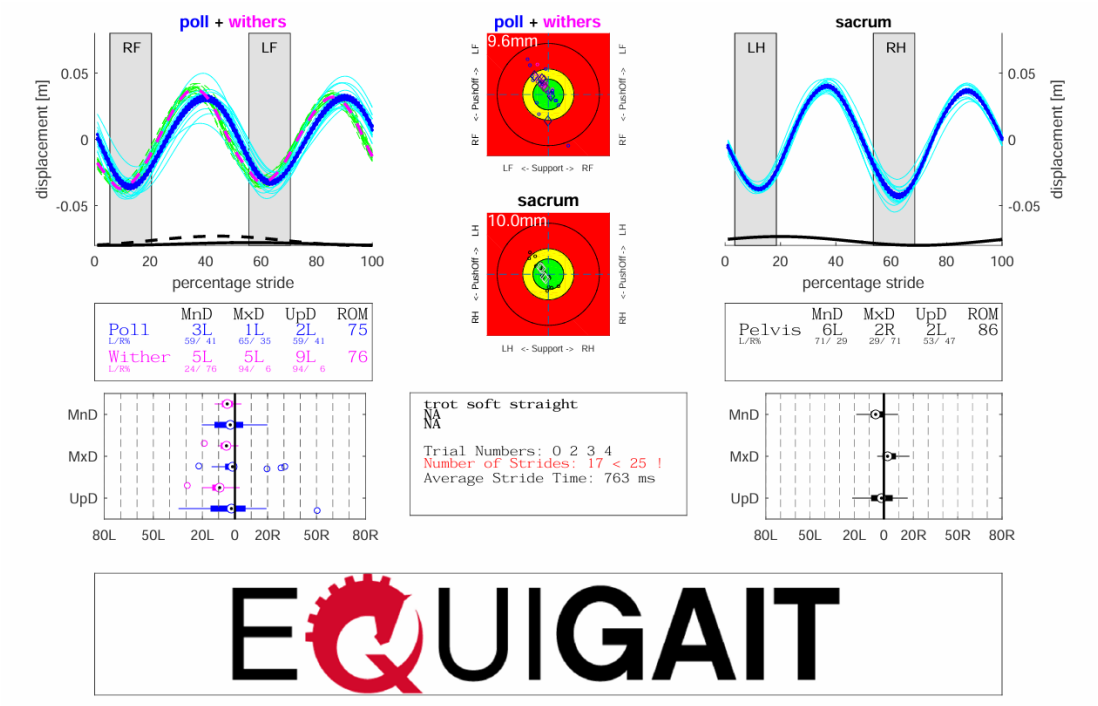
Horse 5



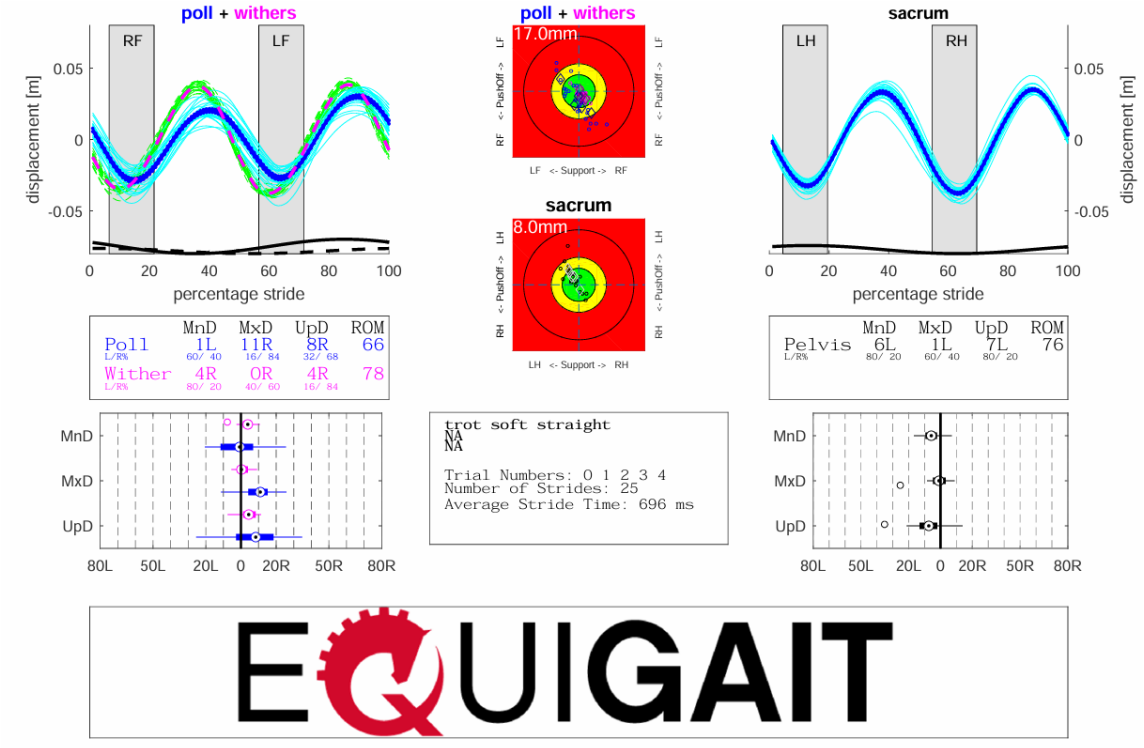
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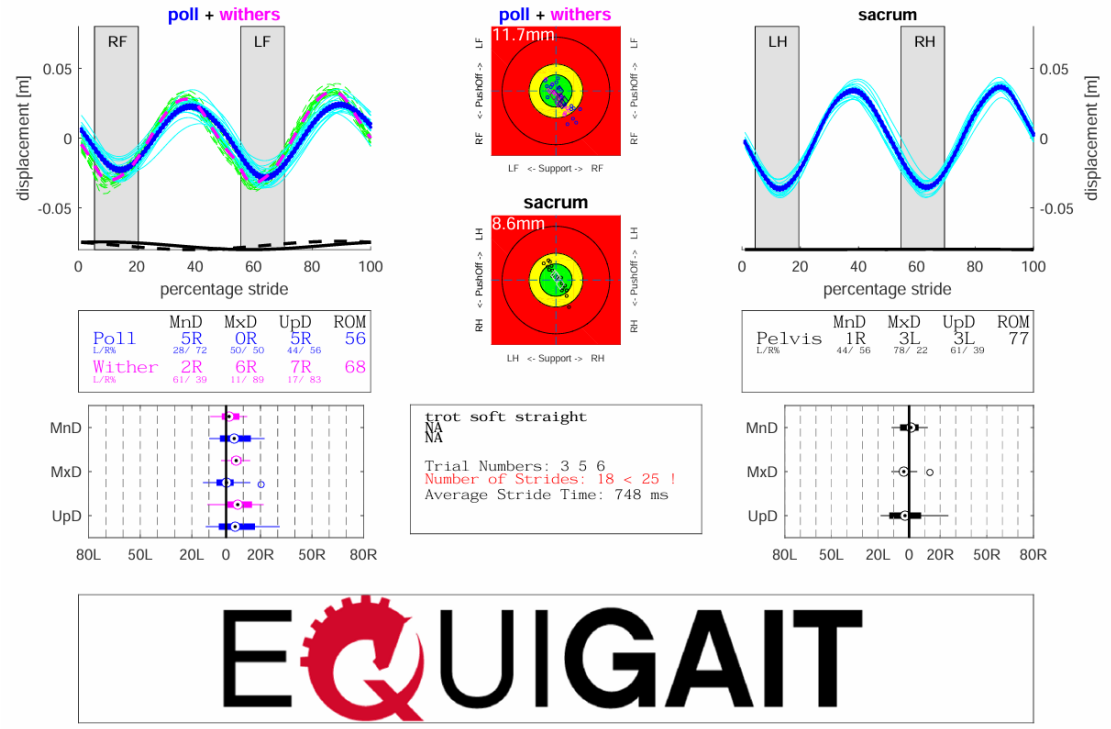
Horse 7



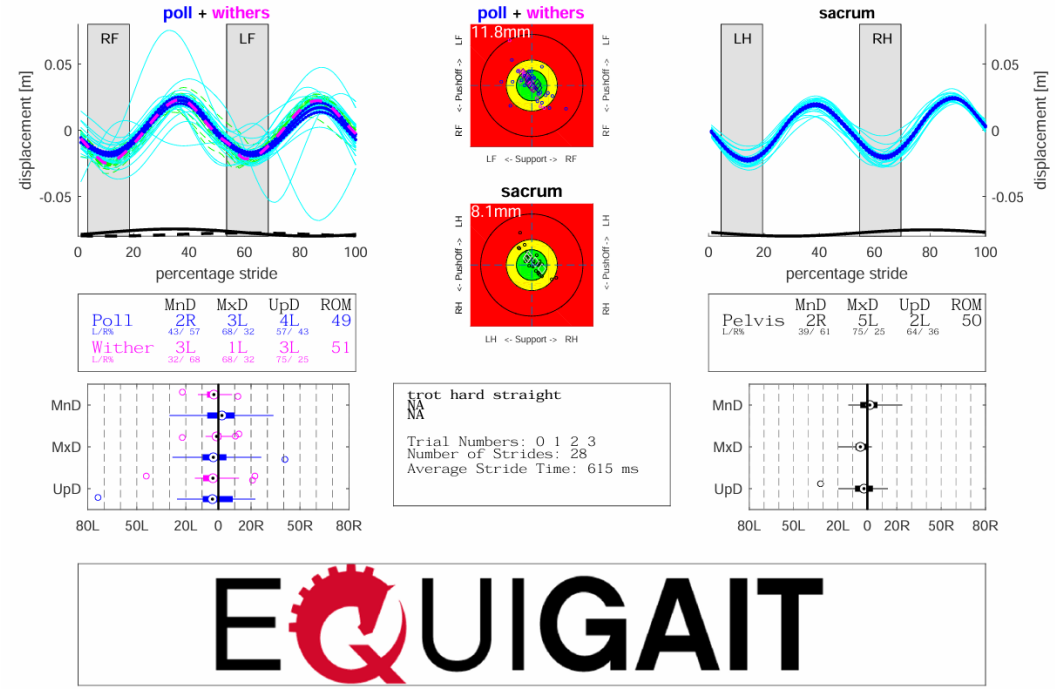
Horse 8



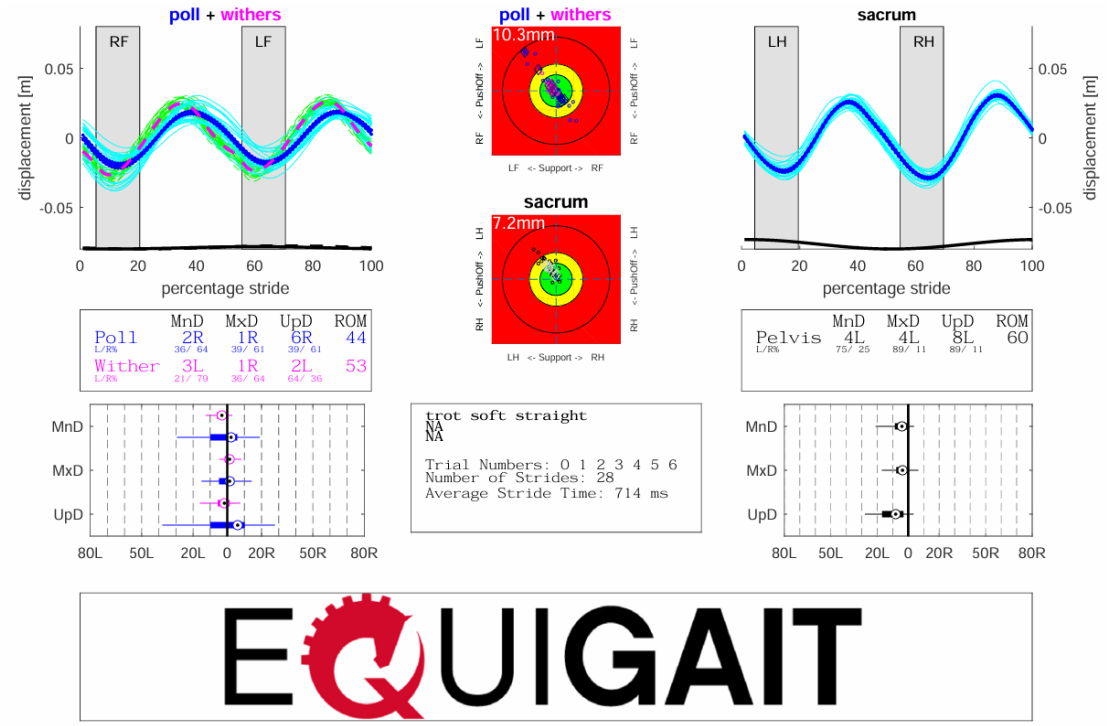
Horse 9



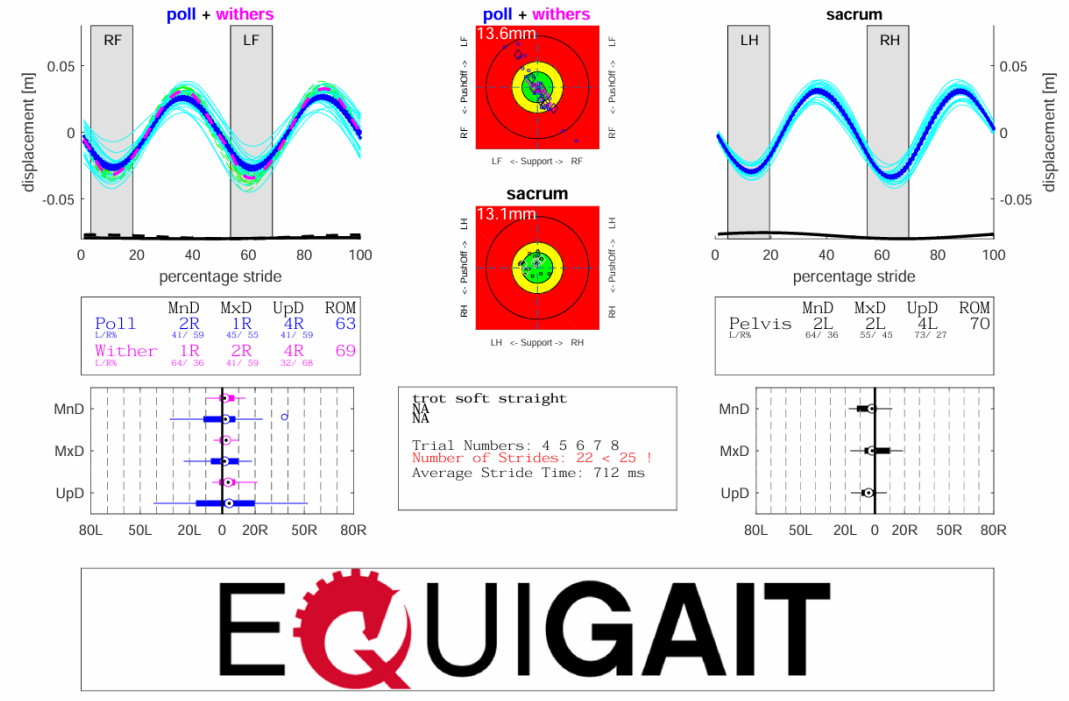
Horse 10



Horse 11

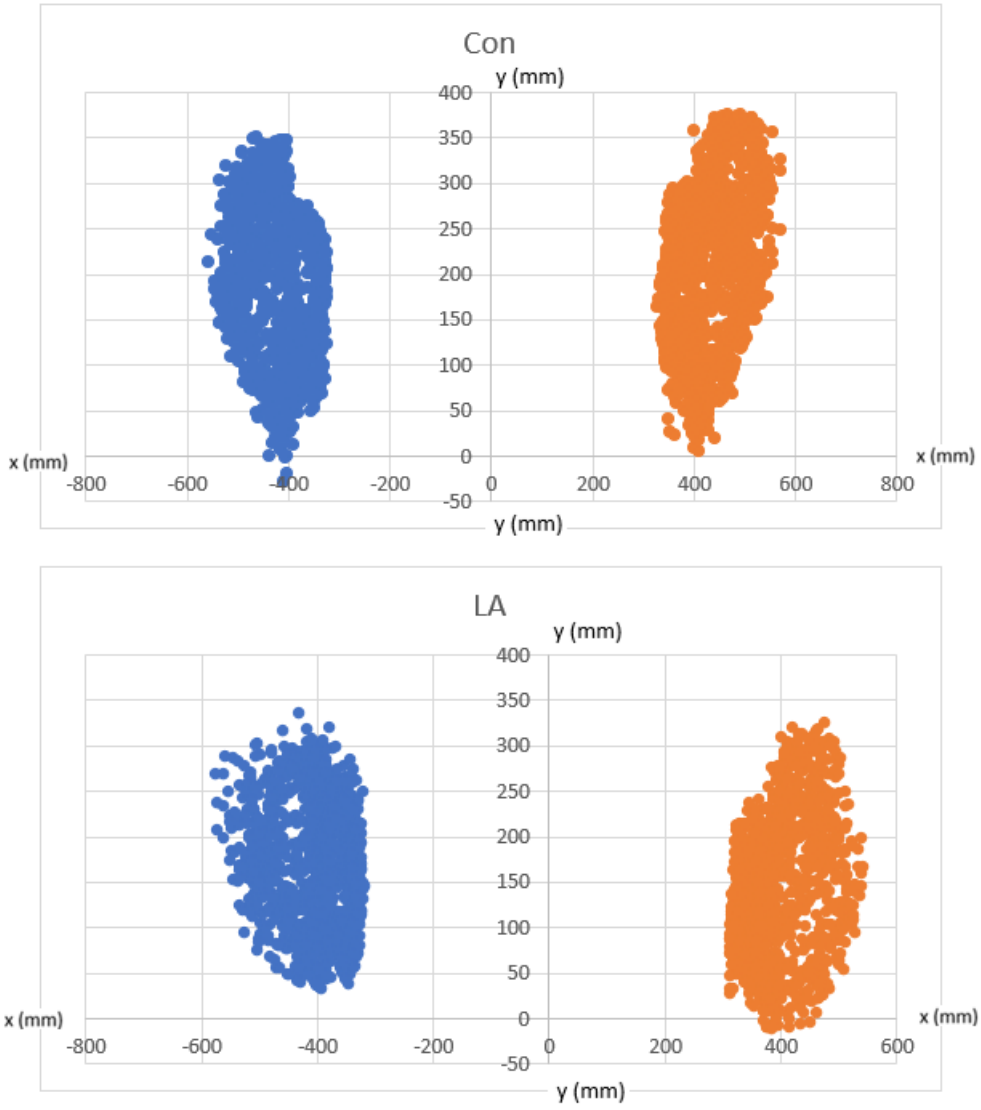


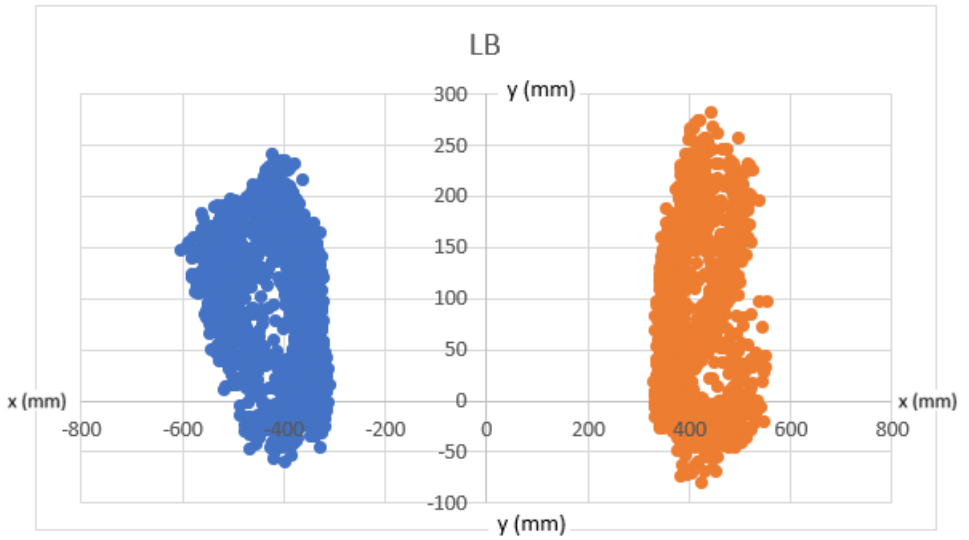
Horse 12

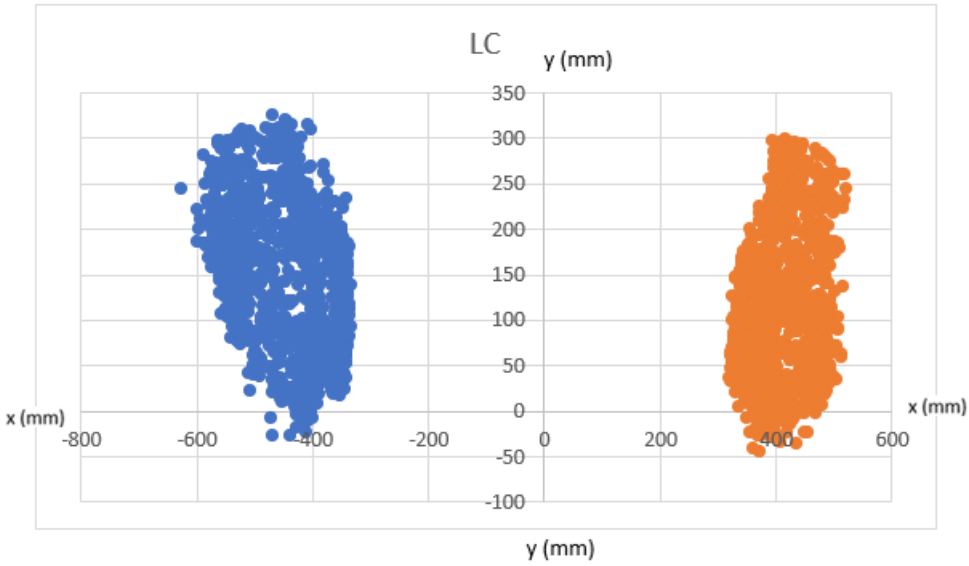


Annex 3: Visual representation of the ROM of the COP per horse and saddle in mm. Every dot marks a coordinate position. Con = Saddle with a conventional saddle tree, LA = Leathertree dressage saddle A, LB = Leathertree dressage saddle B, LC = Leathertree dressage saddle C, with = with rider, without = without rider

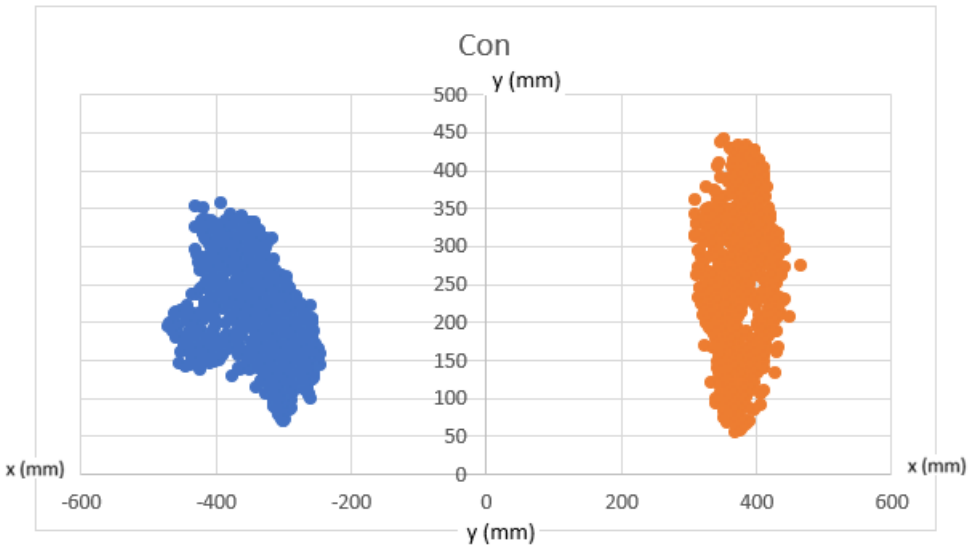
Horse 1

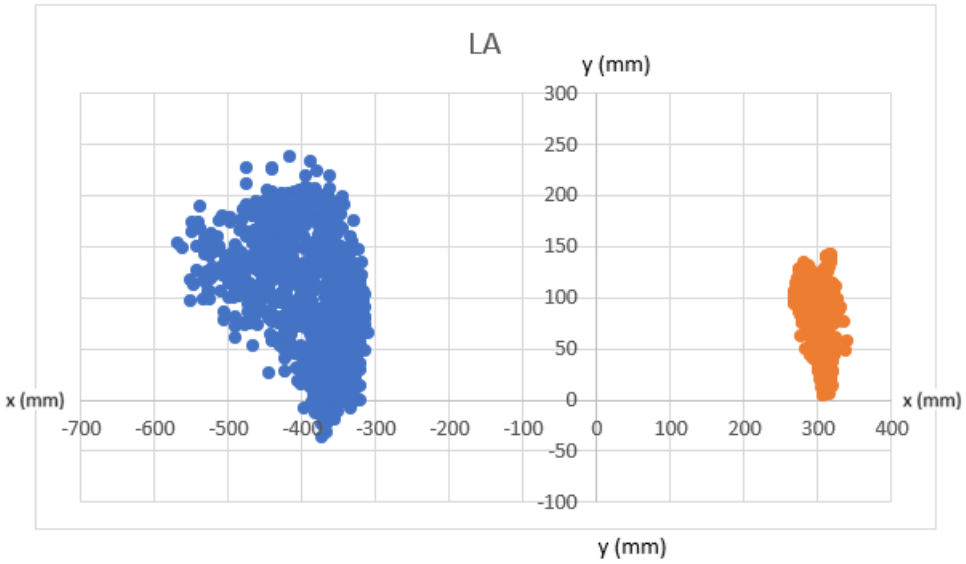


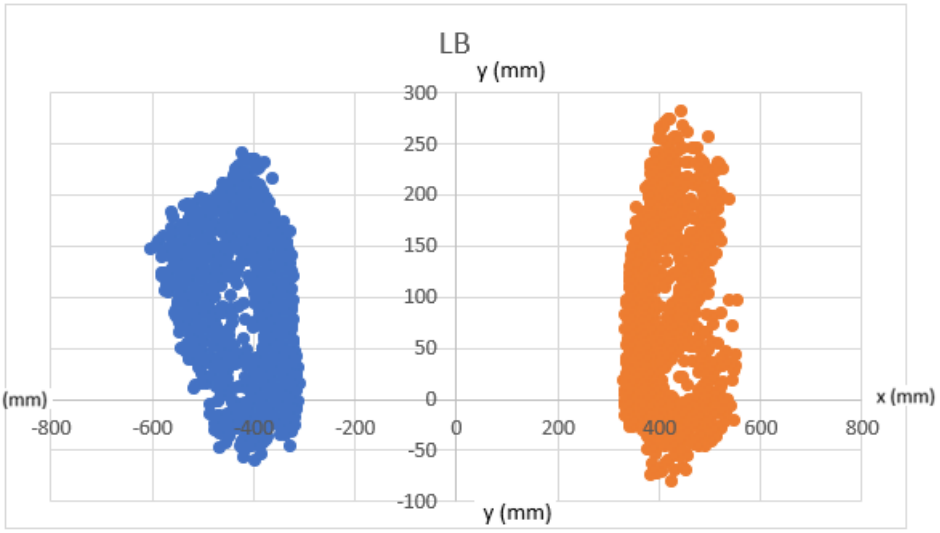

LB
y (mm)
300
250
200
150
100
50
0
-50
-100
x (mm)
-800
-600
-400
-200
0
200
400
600
800
x (mm)
y (mm)

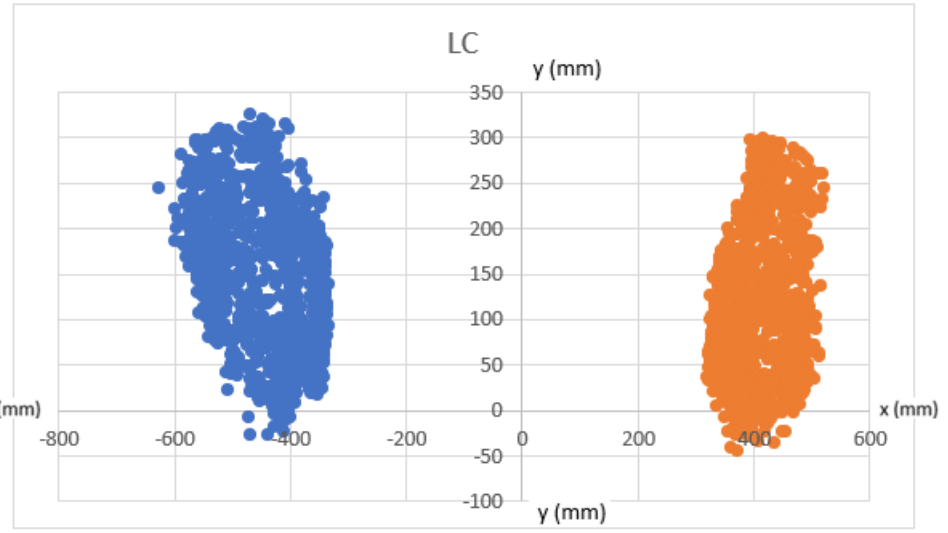

LC
y (mm)
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-800
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

Horse 2

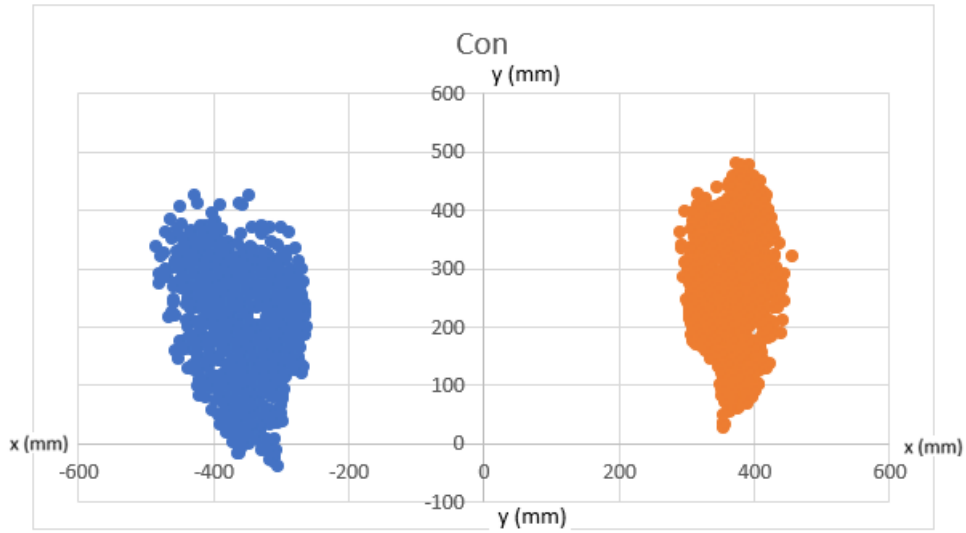

Con
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-600
-400
-200
0
200
400
600
y (mm)
x (mm)

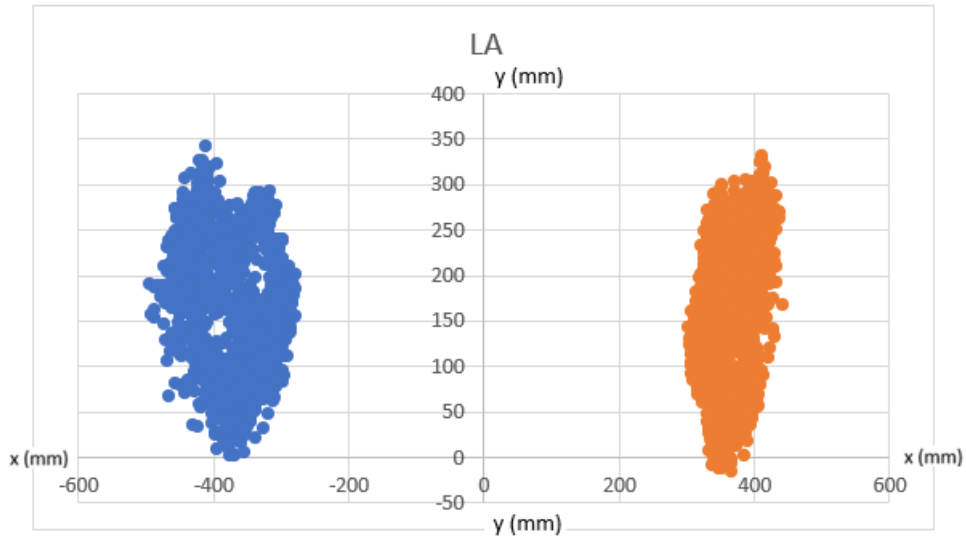

LA
y (mm)
300
250
200
150
100
50
0
-50
-100
x (mm)
-700
-600
-500
-400
-300
-200
-100
0
100
200
300
400
y (mm)
x (mm)

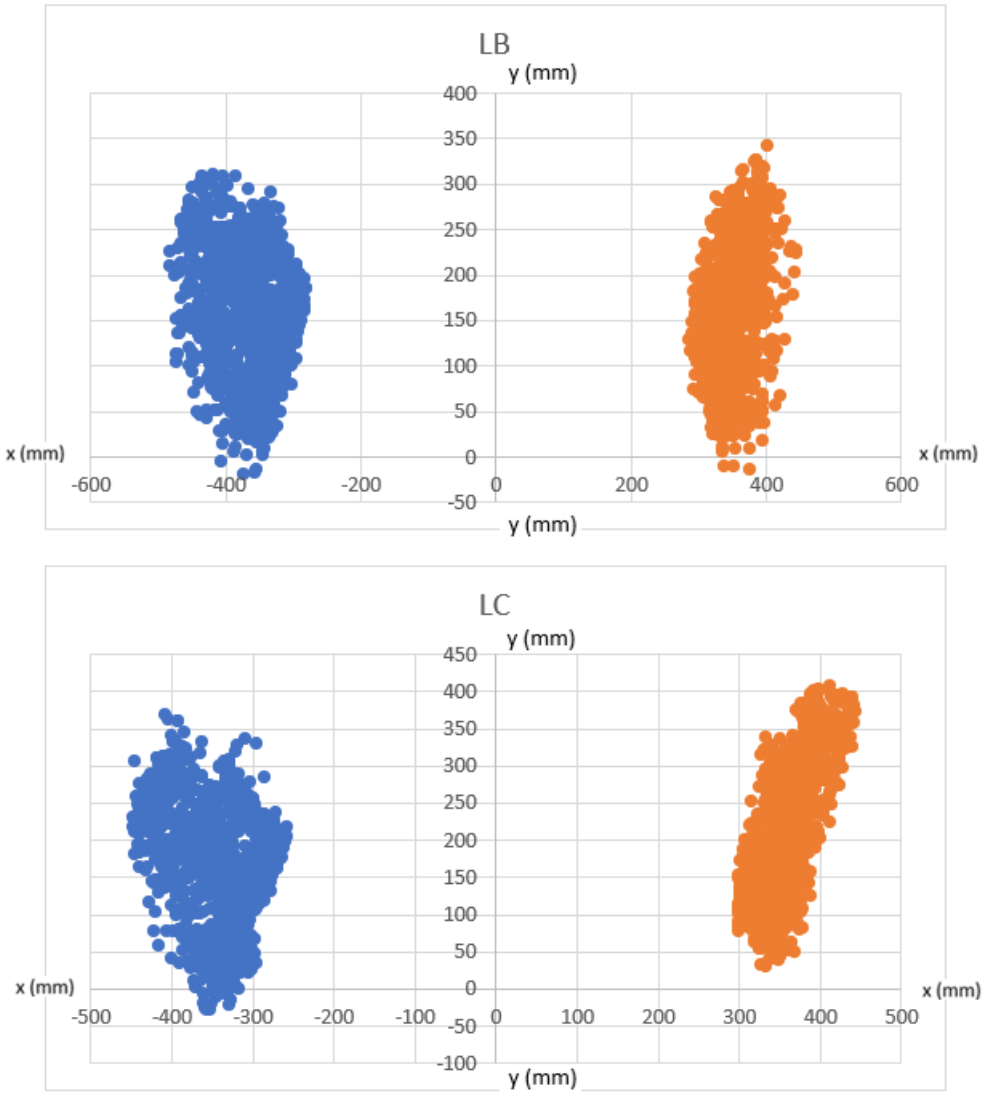

LB
y (mm)
300
250
200
150
100
50
0
-50
-100
x (mm)
-800
-600
-400
-200
0
200
400
600
800
x (mm)
y (mm)


LC
y (mm)
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-800
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

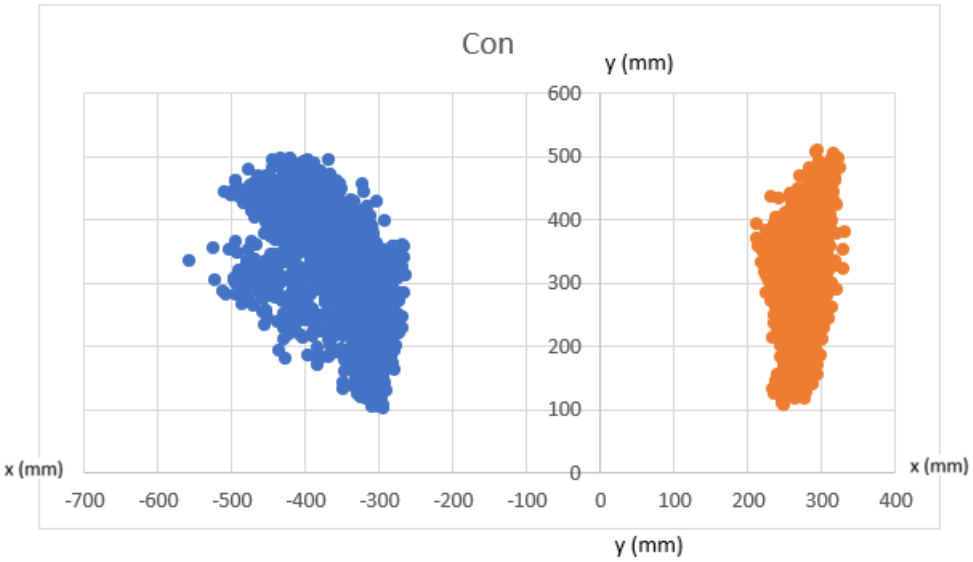
Horse 3

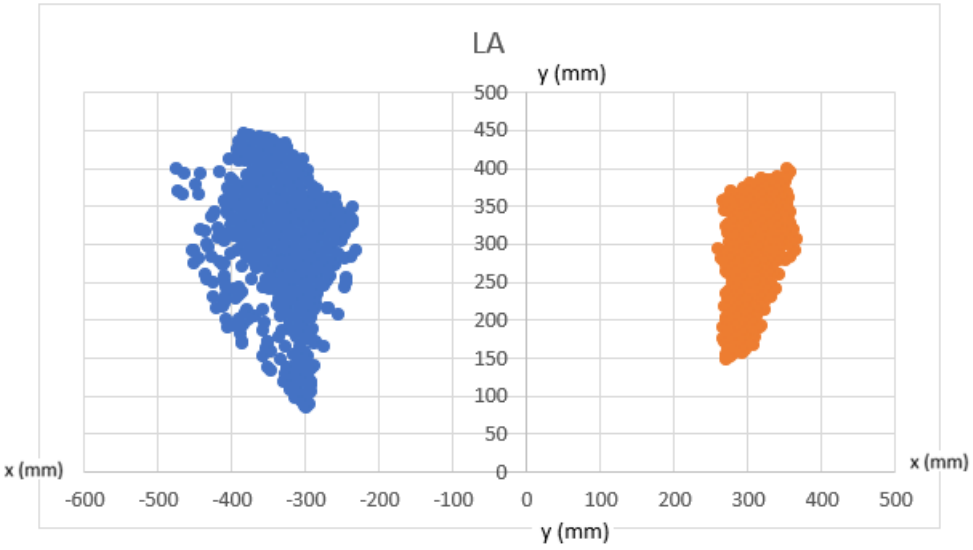

Con
y (mm)
600
500
400
300
200
100
0
-100
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

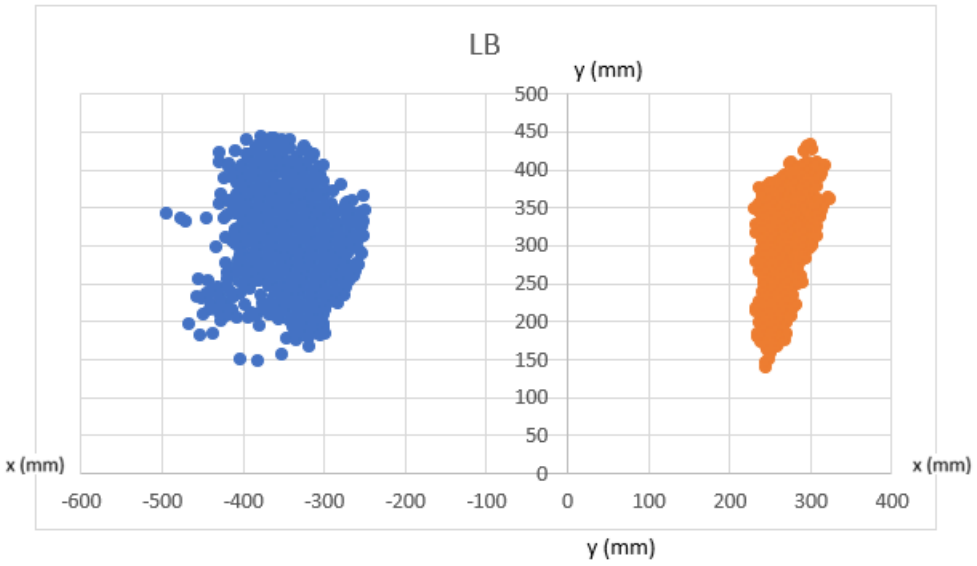

LA
y (mm)
400
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

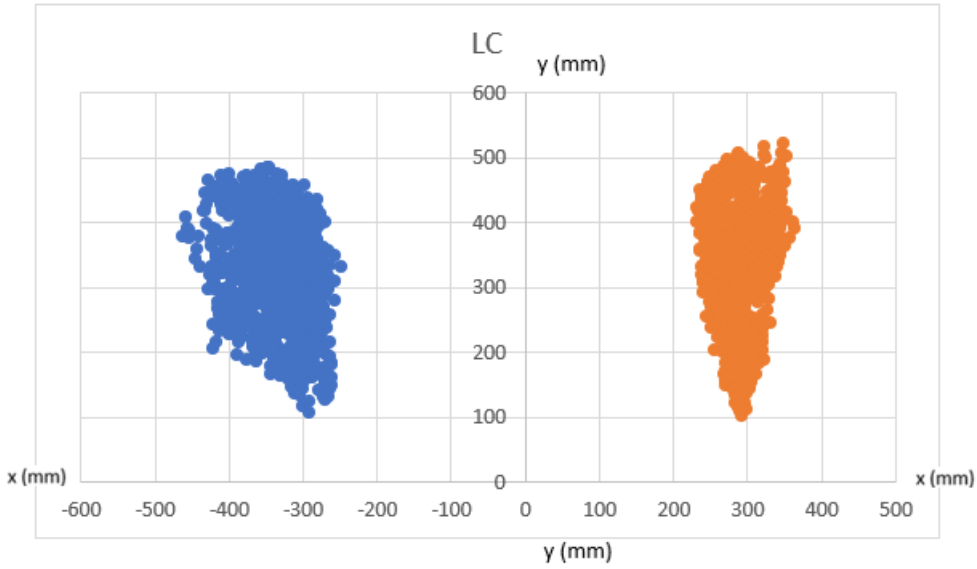

LB
y (mm)
400
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)
LC
y (mm)
450
400
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-500
-400
-300
-200
-100
0
100
200
300
400
500
x (mm)
y (mm)

Horse 4

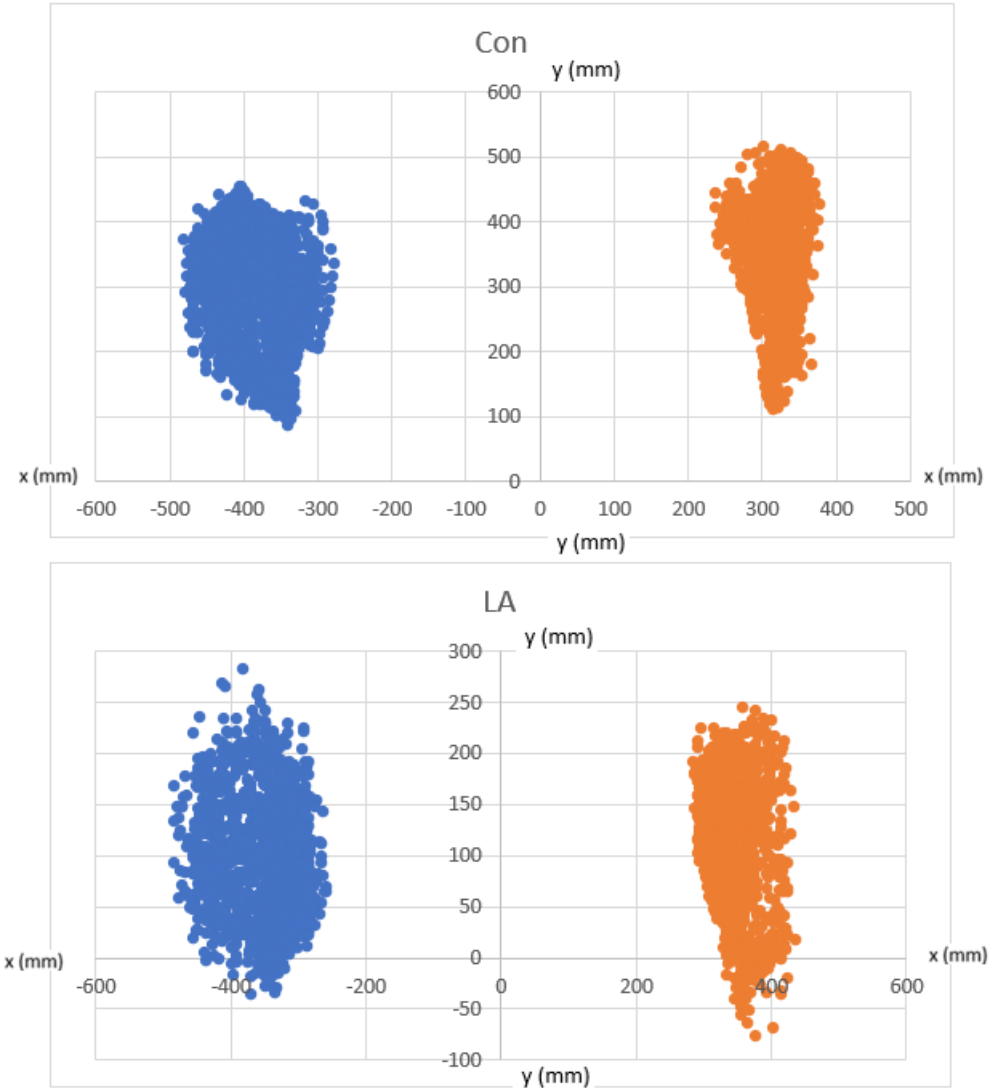

Con
y (mm)
600
500
400
300
200
100
0
x (mm)
-700
-600
-500
-400
-300
-200
-100
0
100
200
300
400
y (mm)
x (mm)

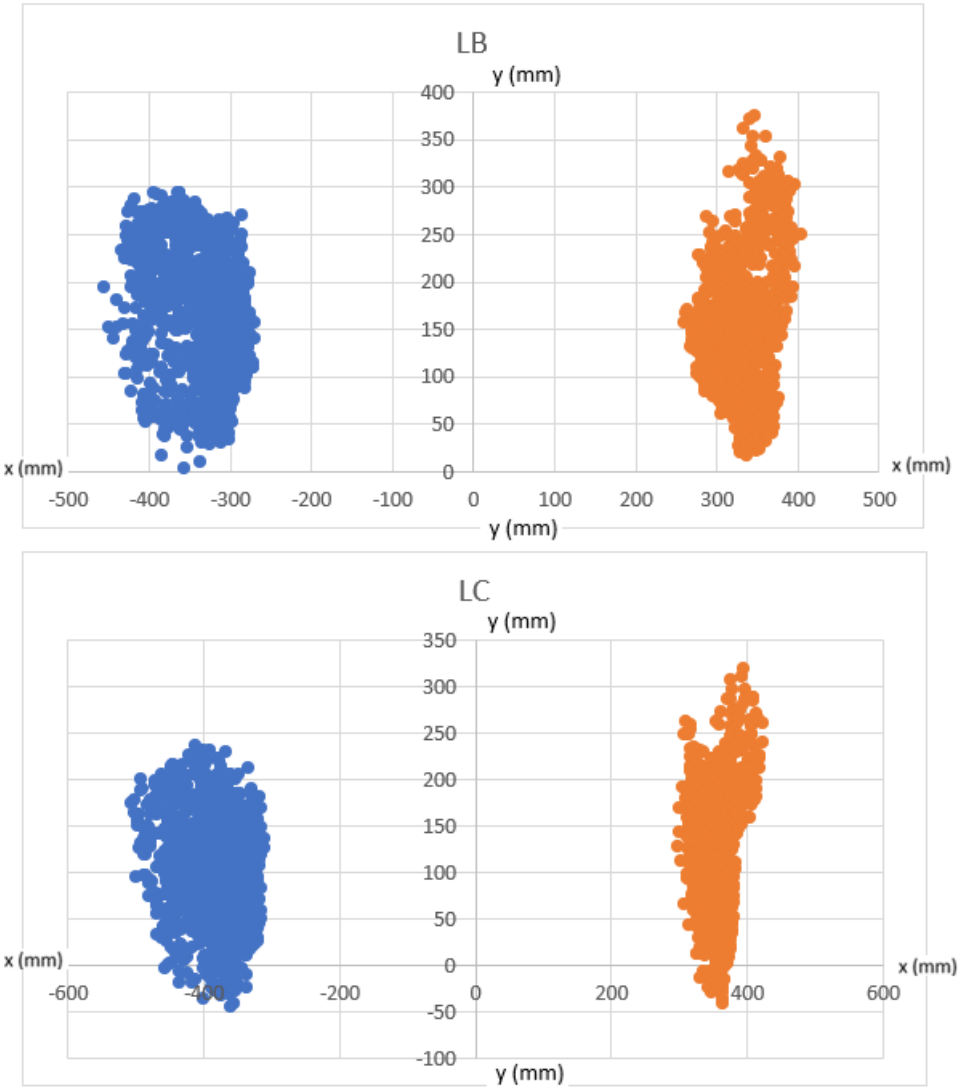

LA
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
y (mm)
x (mm)


LB
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-600
-500
-400
-300
-200
-100
0
100
200
300
400
x (mm)
y (mm)

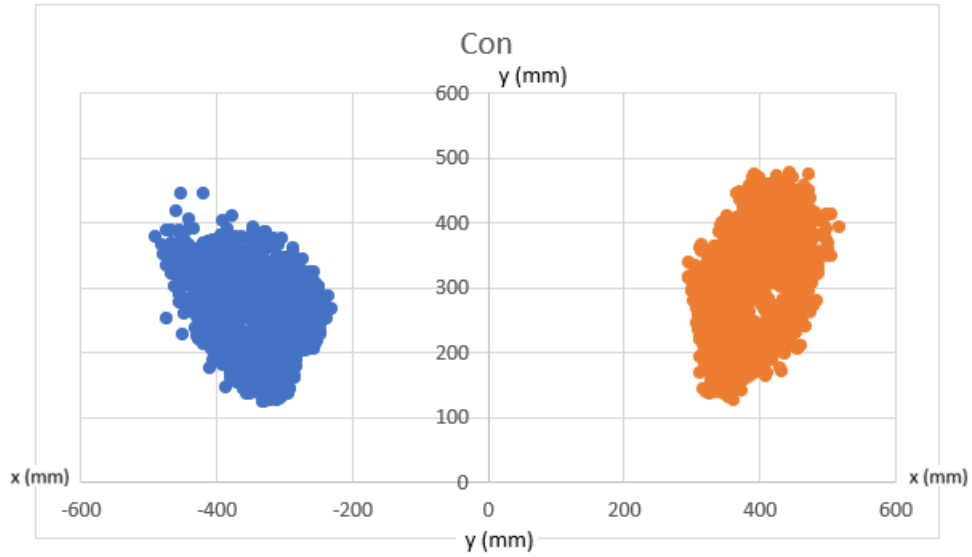

LC
y (mm)
600
500
400
300
200
100
0
x (mm)
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
x (mm)
y (mm)

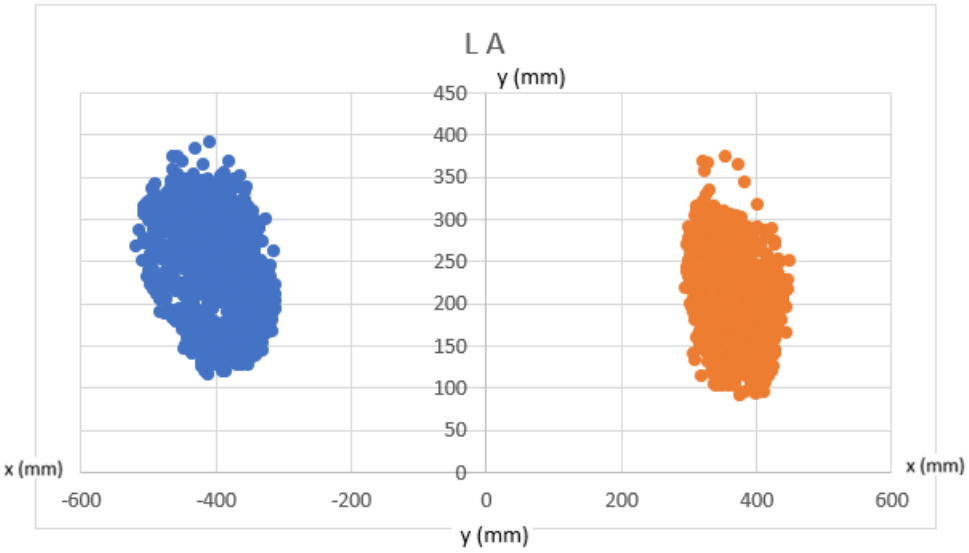
Horse 5

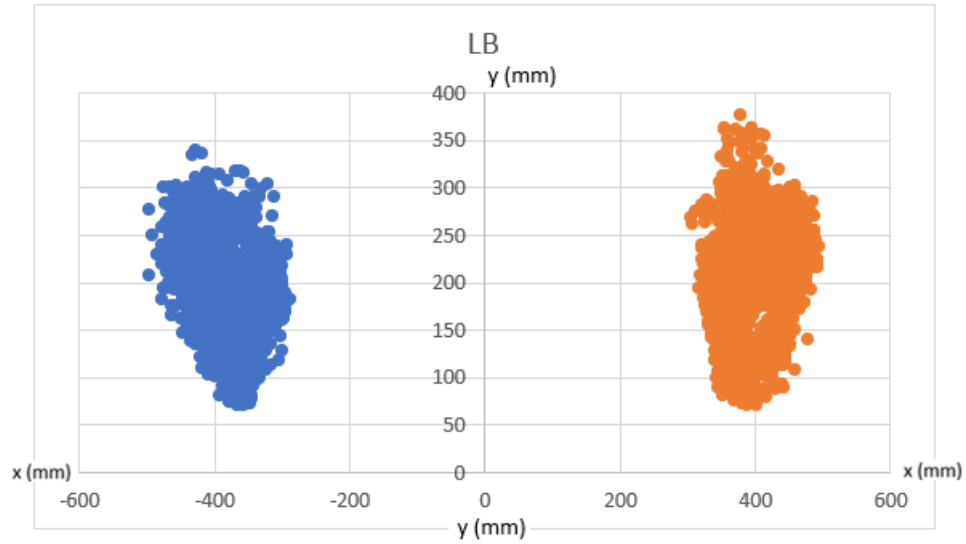

Con
y (mm)
600
500
400
300
200
100
0
x (mm)
x (mm)
-600 -500 -400 -300 -200 -100 0 100 200 300 400 500
y (mm)
LA
y (mm)
300
250
200
150
100
50
0
-50
-100
x (mm)
x (mm)
-600 -400 -200 0 200 400 600
y (mm)

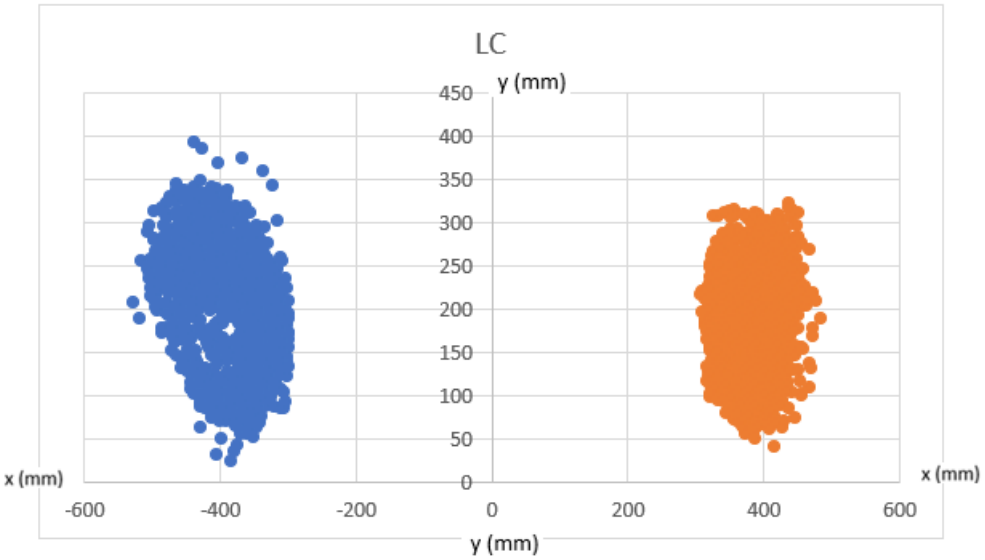

LB
y (mm)
400
350
300
250
200
150
100
50
0
x (mm)
-500
-400
-300
-200
-100
0
100
200
300
400
500
x (mm)
y (mm)
LC
y (mm)
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-600
-200
0
200
400
600
x (mm)
y (mm)

Horse 6

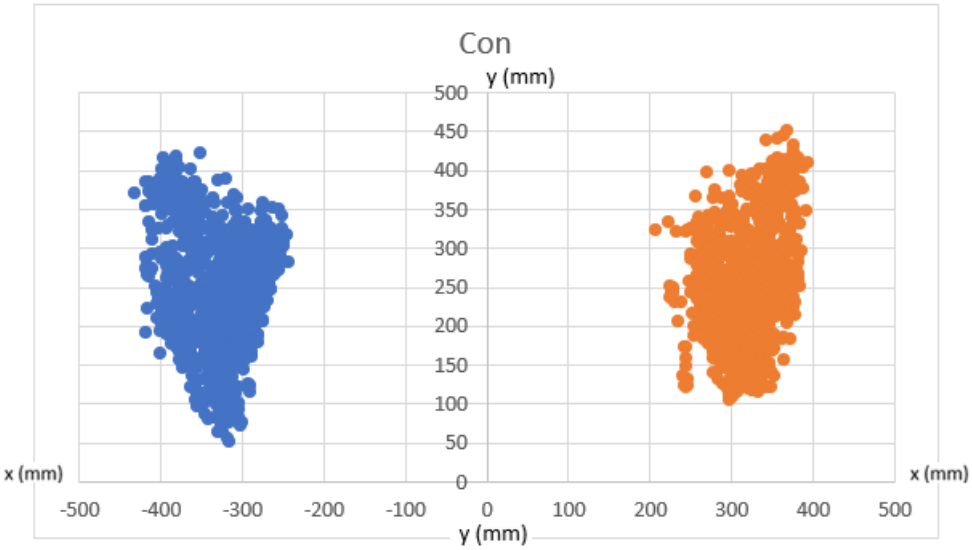

Con
y (mm)
600
500
400
300
200
100
0
x (mm)
x (mm)
-600
-400
-200
0
200
400
600
y (mm)

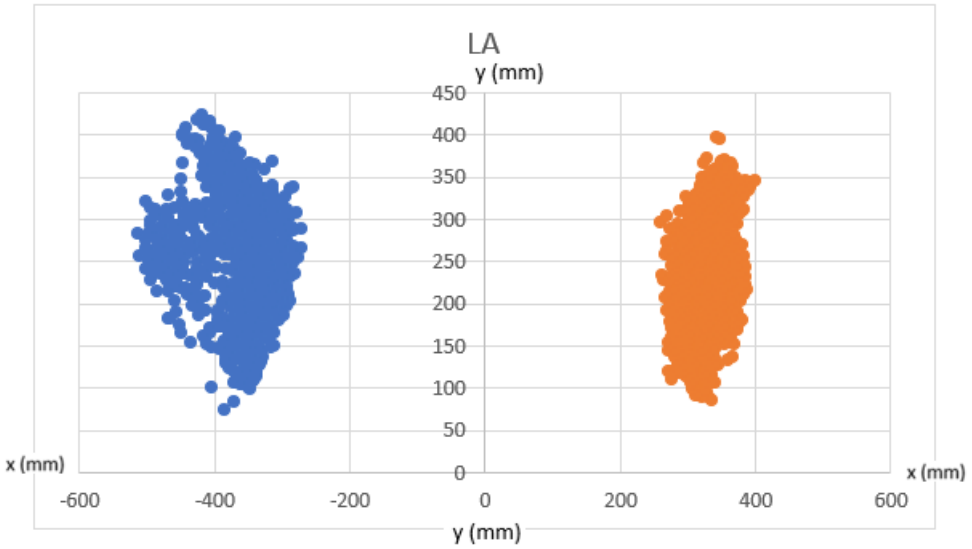

L A
y (mm)
450
400
350
300
250
200
150
100
50
0
x (mm)
x (mm)
-600
-400
-200
0
200
400
600
y (mm)

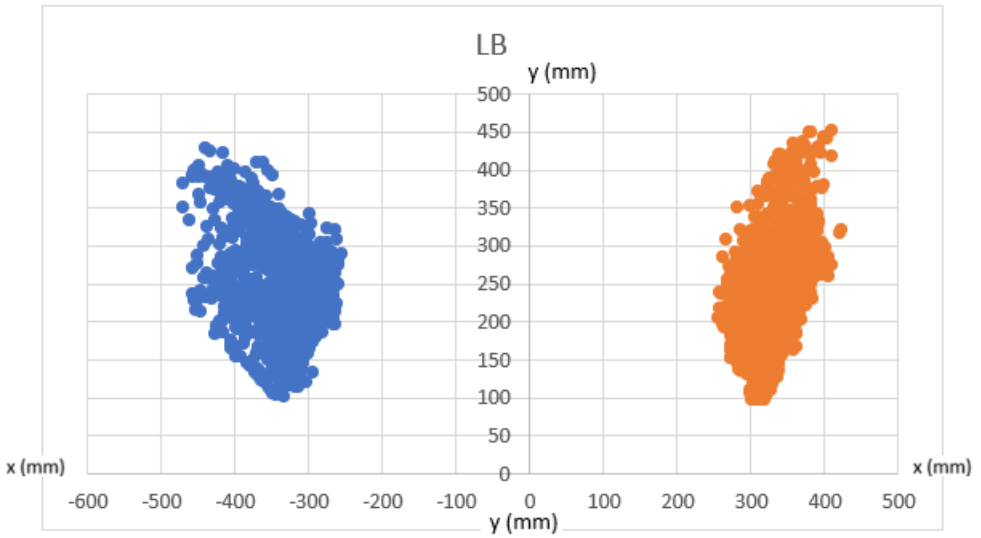

LB
y (mm)
400
350
300
250
200
150
100
50
0
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

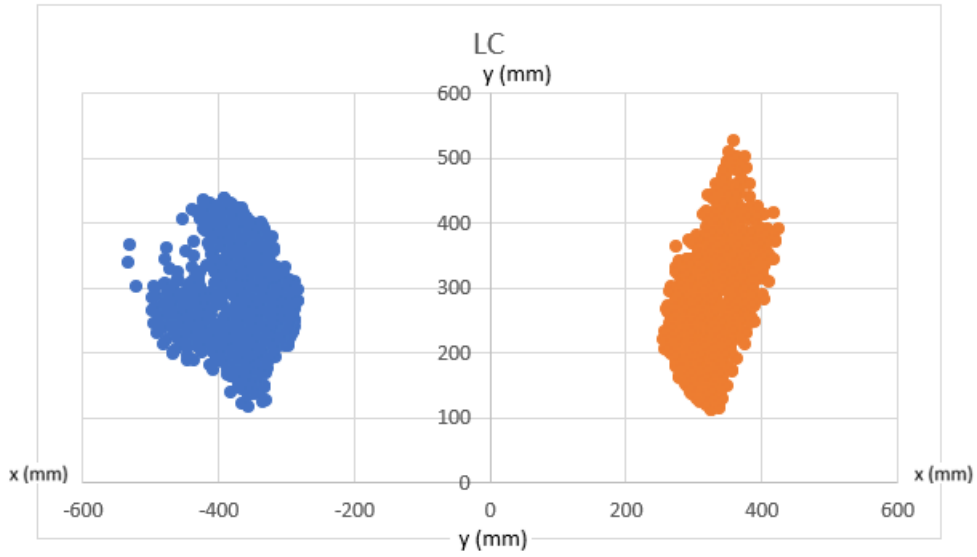

LC
y (mm)
450
400
350
300
250
200
150
100
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0
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

Horse 7

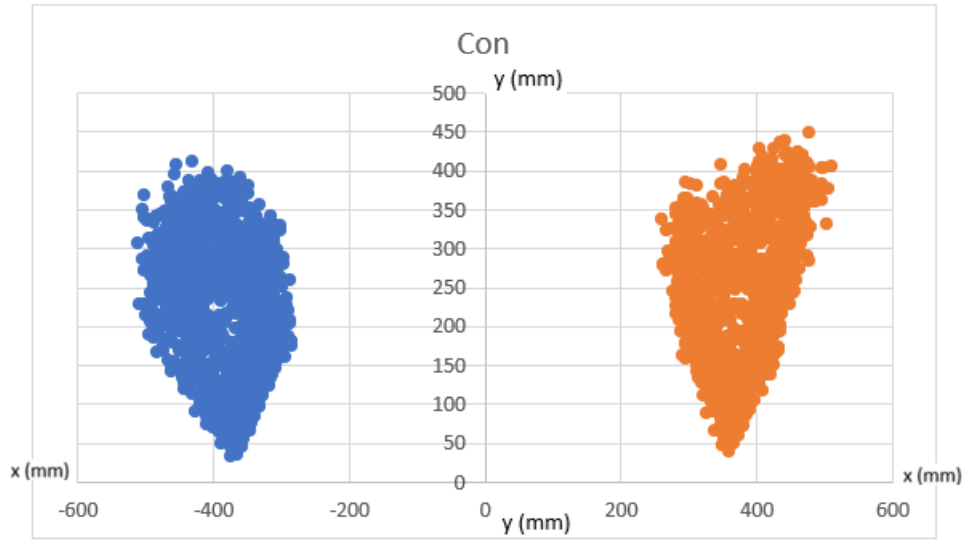

Con
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
x (mm)
-500
-400
-300
-200
-100
0
100
200
300
400
500
y (mm)

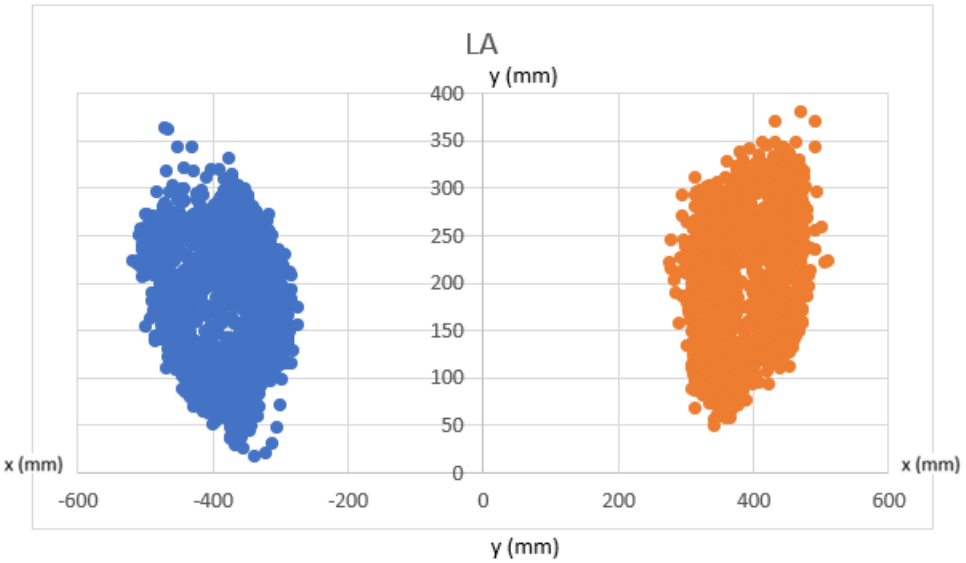

LA
y (mm)
450
400
350
300
250
200
150
100
50
0
x (mm)
x (mm)
-600
-400
-200
0
200
400
600
y (mm)

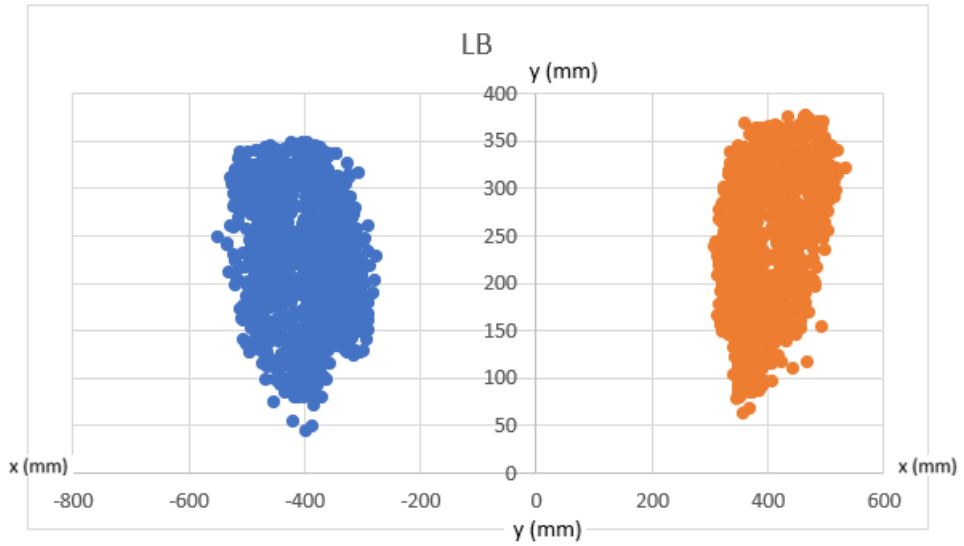

LB
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
x (mm)
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
y (mm)

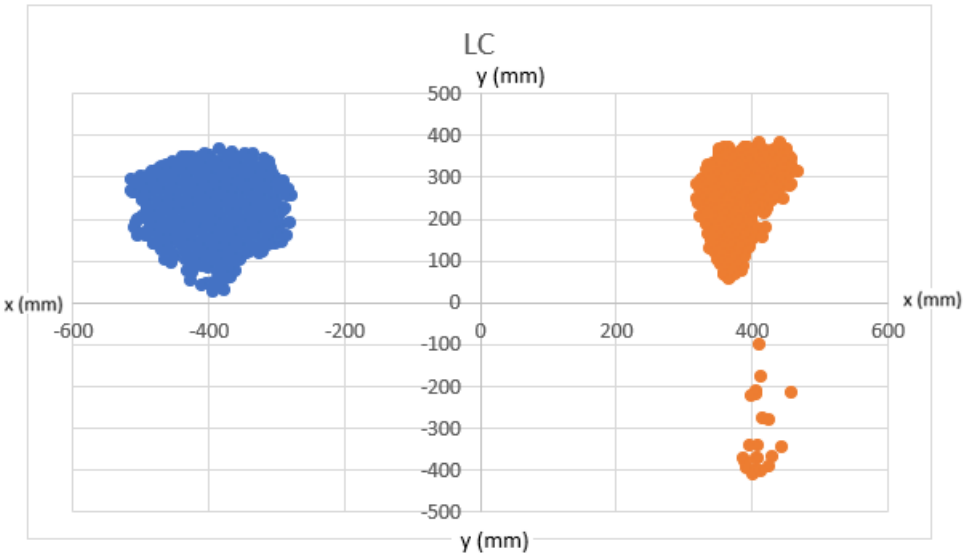

LC
y (mm)
600
500
400
300
200
100
0
x (mm)
x (mm)
-600
-400
-200
0
200
400
600
y (mm)

Horse 8

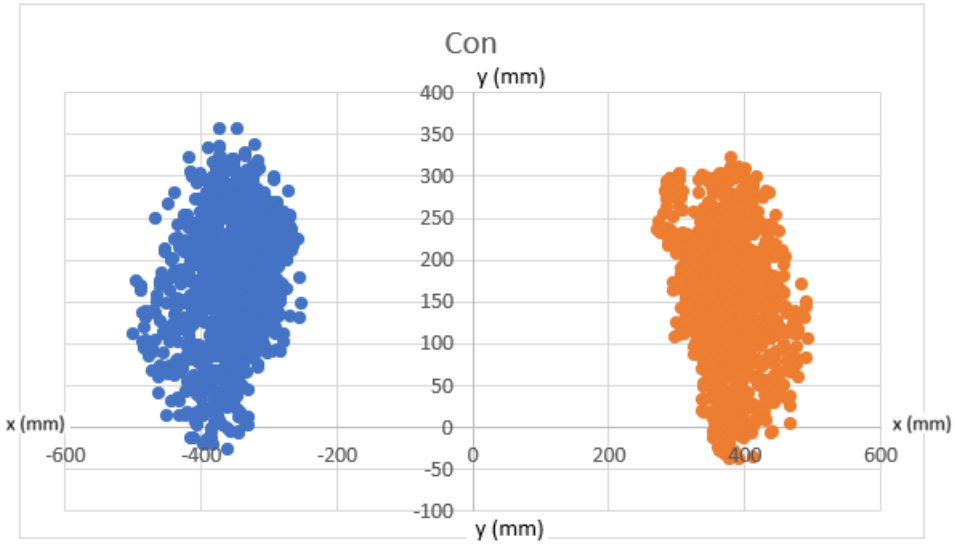

Con
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-600
-400
-200
0
200
400
600
y (mm)
x (mm)

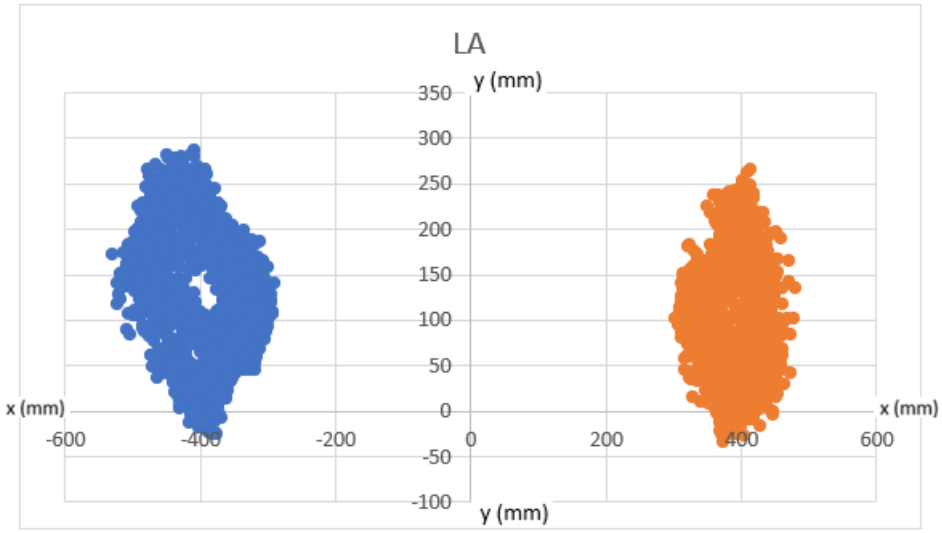

LA
y (mm)
400
350
300
250
200
150
100
50
0
x (mm)
-600
-400
-200
0
200
400
600
y (mm)
x (mm)

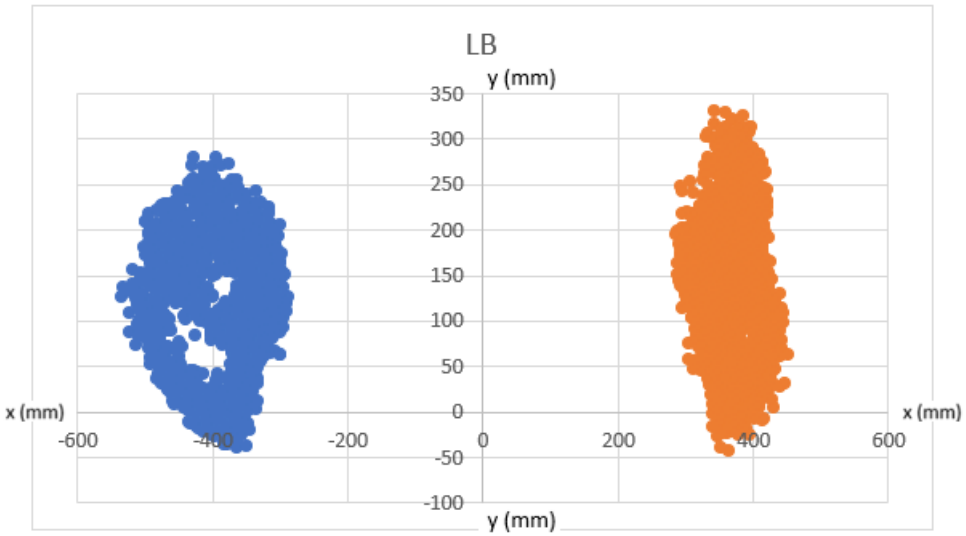

LB
y (mm)
400
350
300
250
200
150
100
50
0
x (mm)
x (mm)
-800
-600
-400
-200
0
200
400
600
y (mm)

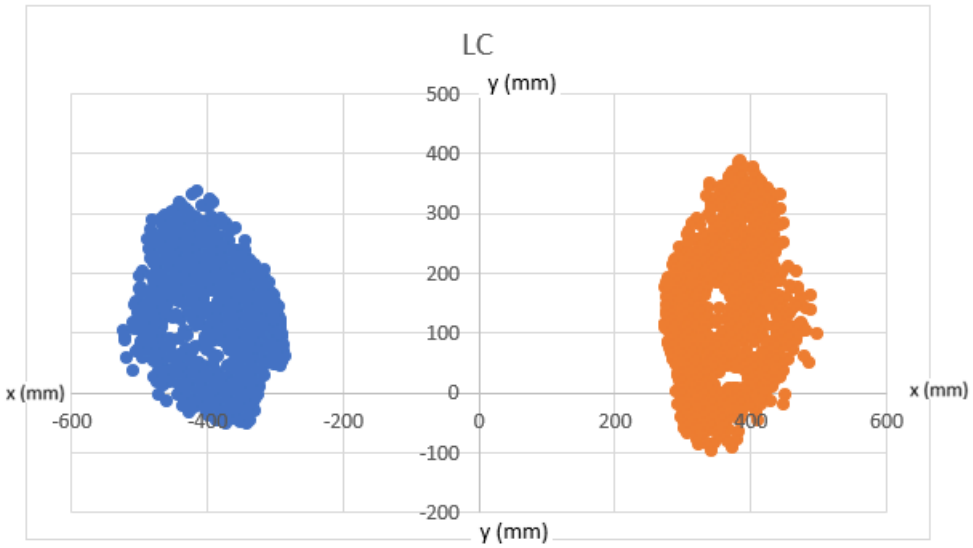

LC
y (mm)
500
400
300
200
100
0
-100
-200
-300
-400
-500
x (mm)
x (mm)
-600
-400
-200
0
200
400
600
y (mm)

Horse 9

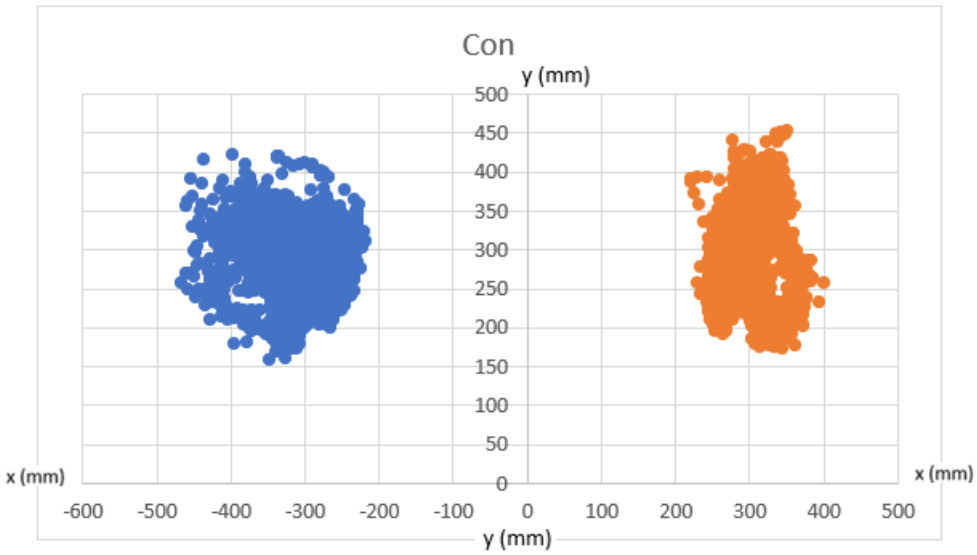

Con
y (mm)
400
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

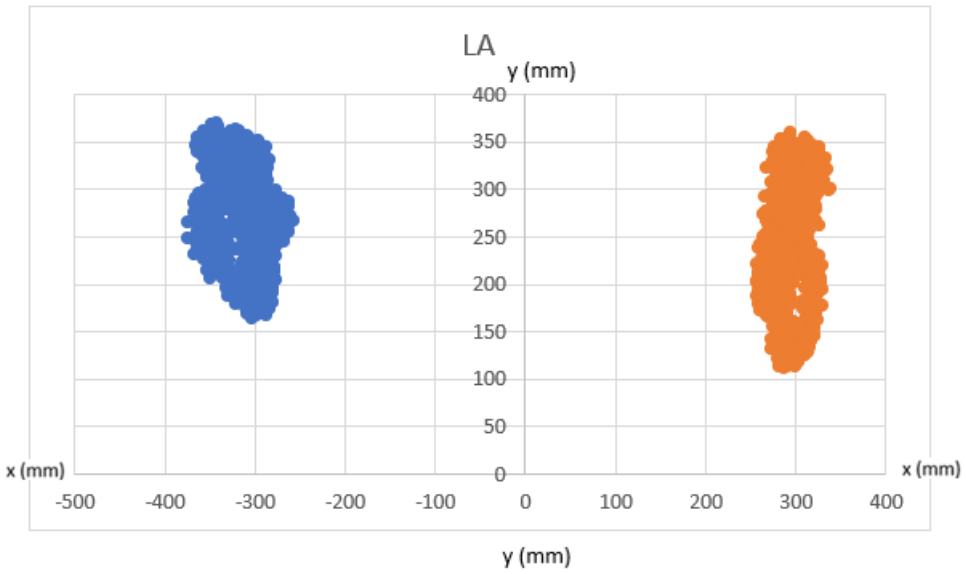

LA
y (mm)
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

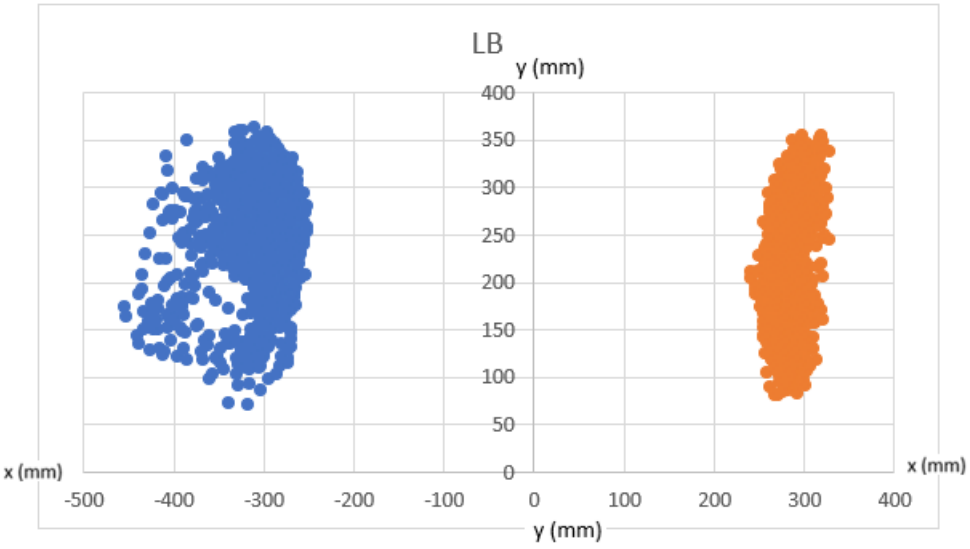

LB
y (mm)
350
300
250
200
150
100
50
0
-50
-100
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

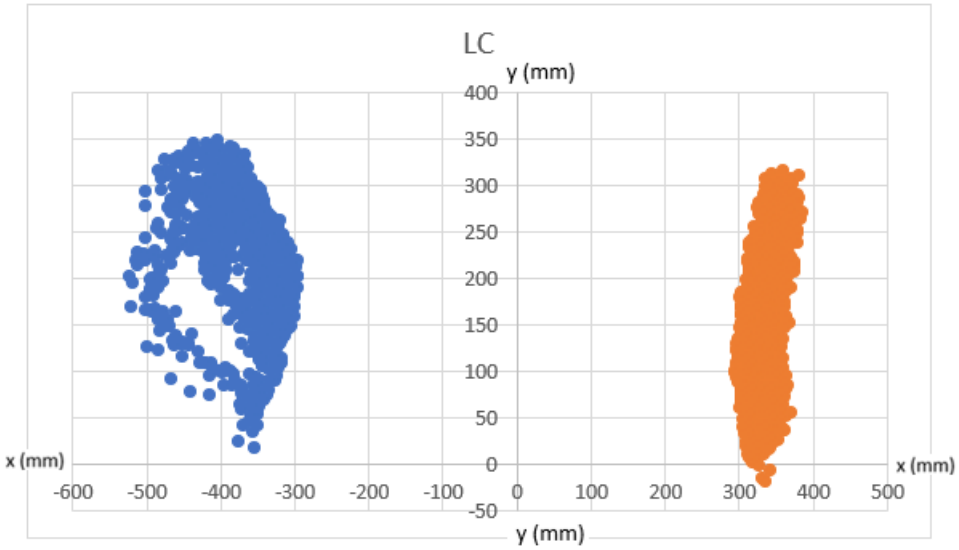

LC
y (mm)
500
400
300
200
100
0
-100
-200
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

Horse 10

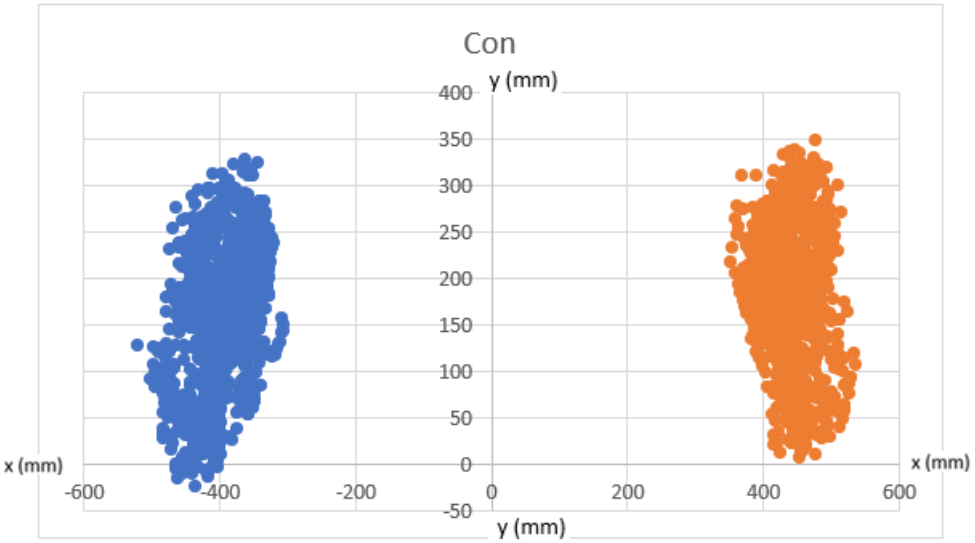

Con
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
x (mm)
y (mm)

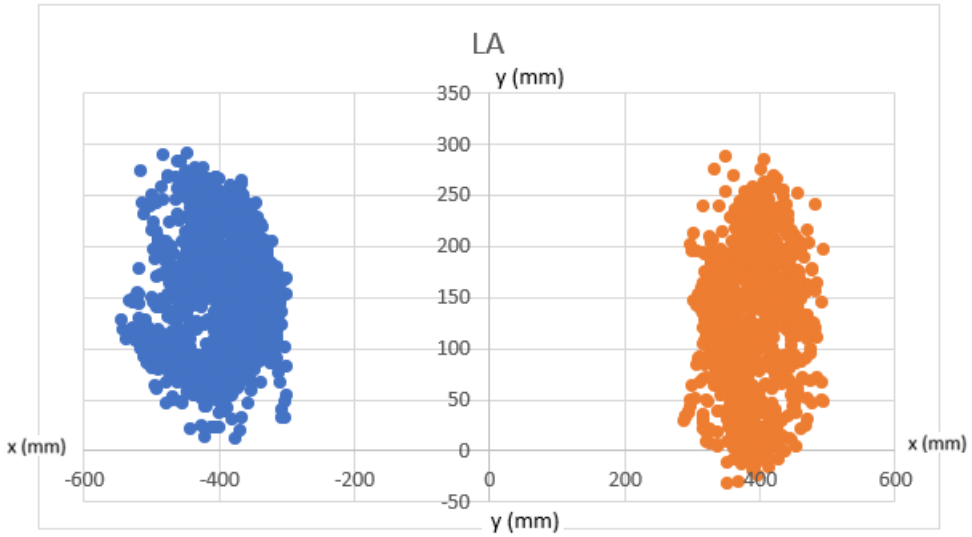

LA
y (mm)
400
350
300
250
200
150
100
50
0
x (mm)
-500
-400
-300
-200
-100
0
100
200
300
400
x (mm)
y (mm)

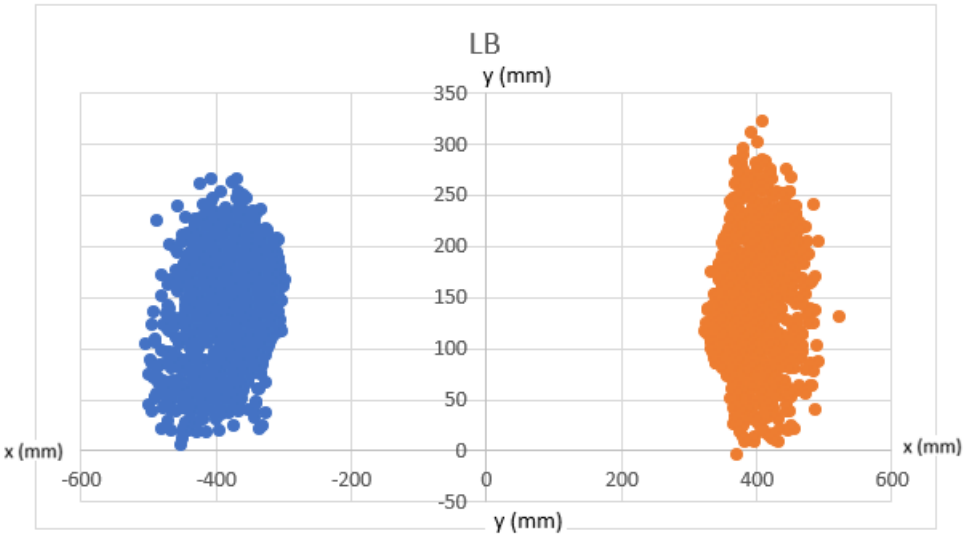

LB
y (mm)
400
350
300
250
200
150
100
50
0
x (mm)
-500
-400
-300
-200
-100
0
100
200
300
400
x (mm)
y (mm)

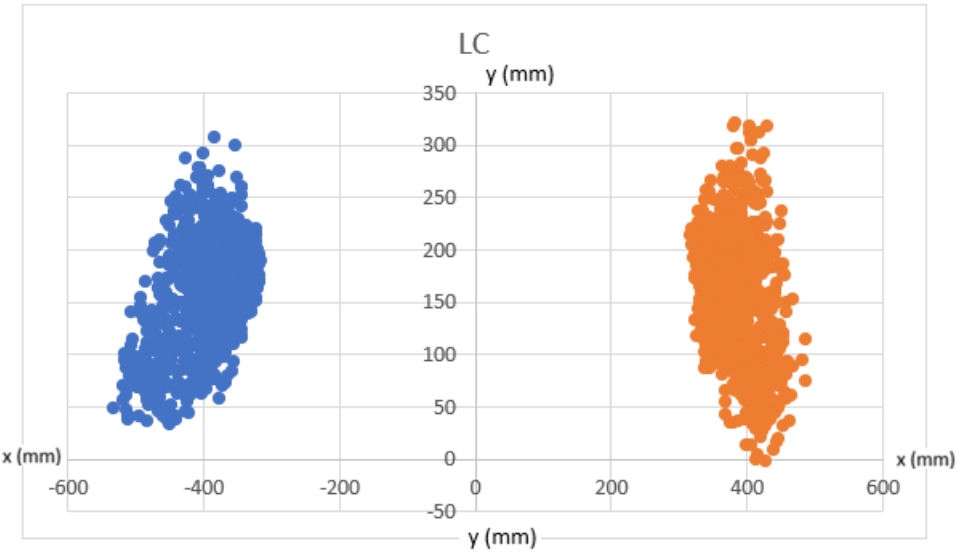

LC
y (mm)
400
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
x (mm)
y (mm)

Horse 11

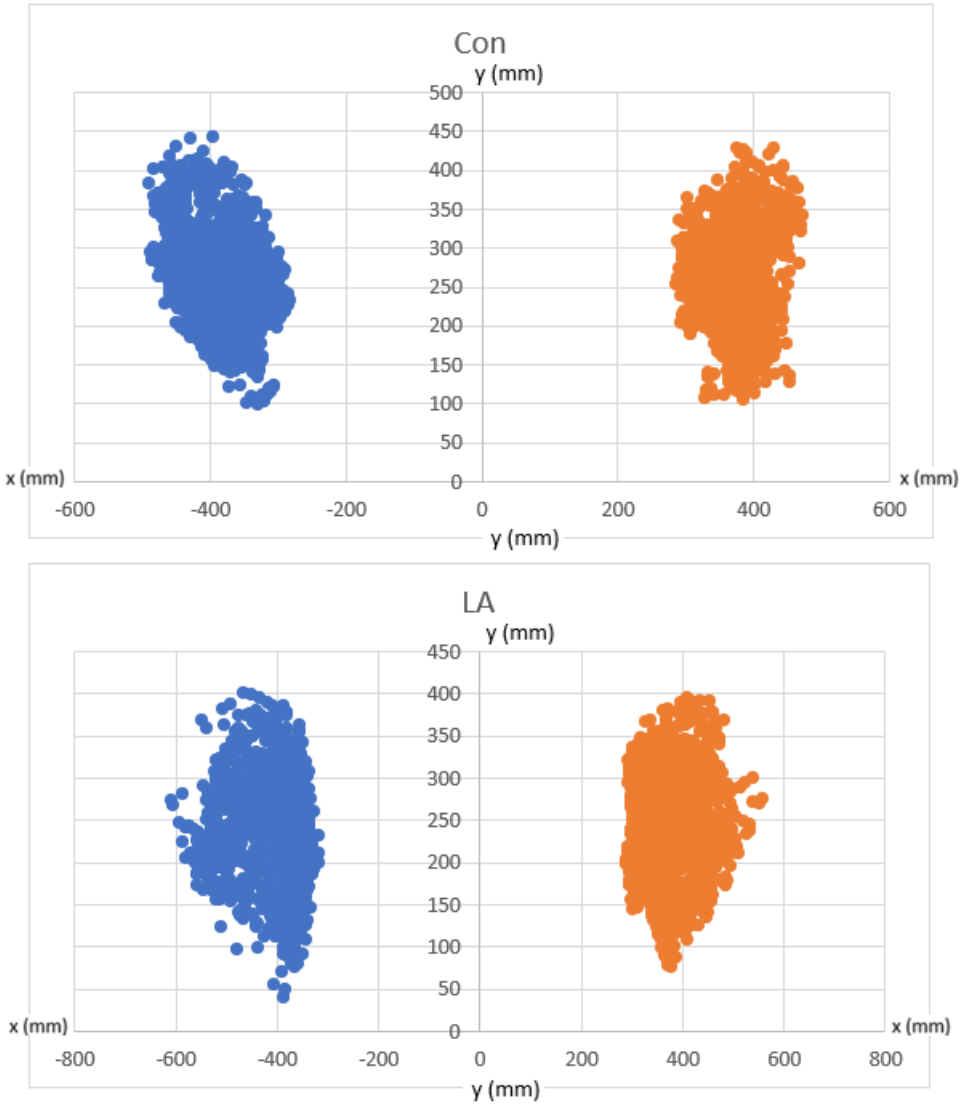

Con
y (mm)
400
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

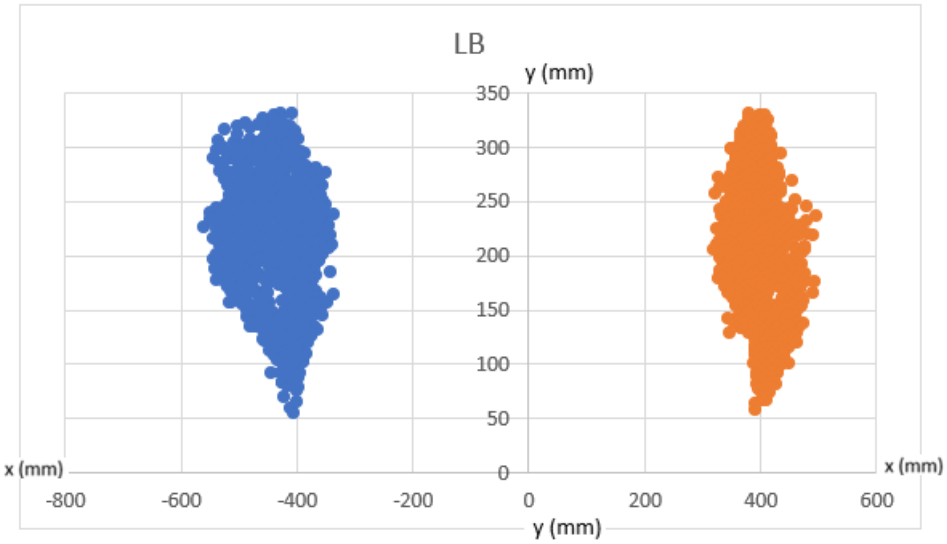

LA
y (mm)
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

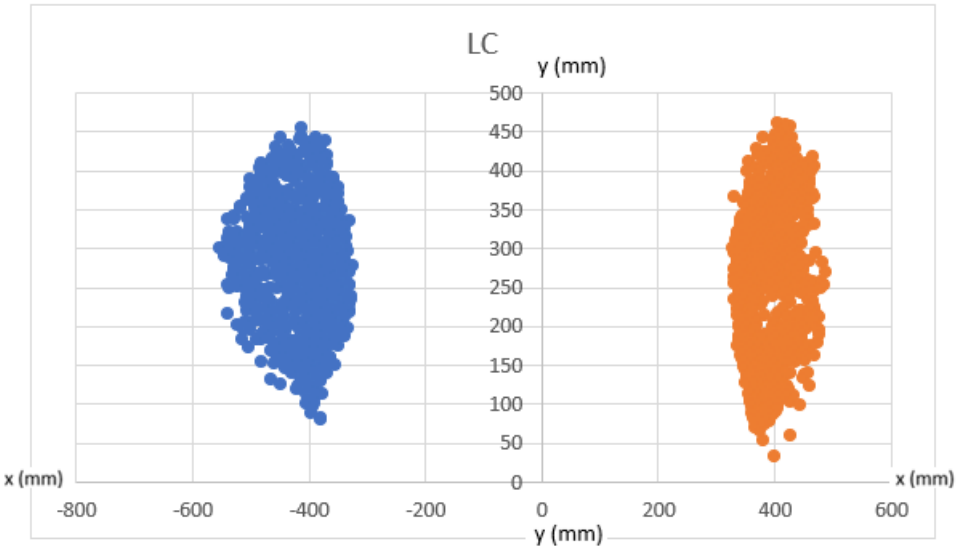

LB
y (mm)
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)


LC
y (mm)
350
300
250
200
150
100
50
0
-50
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)

Horse 12


Con
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-600
-400
-200
0
200
400
600
x (mm)
y (mm)
LA
y (mm)
450
400
350
300
250
200
150
100
50
0
x (mm)
-800
-600
-400
-200
0
200
400
600
800
x (mm)
y (mm)


LB
y (mm)
350
300
250
200
150
100
50
0
x (mm)
-800
-600
-400
-200
0
200
400
600
x (mm)
y (mm)


LC
y (mm)
500
450
400
350
300
250
200
150
100
50
0
x (mm)
-800
-600
-400
-200
0
200
400
600
x (mm)
y (mm)