BS – ritgerð Maí 2025

A descriptive study on three Icelandic horses measuring differences in vertical asymmetry during trot in a straight line and in a circle between two saddle placements using an objective gait analysis system

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10 eininga lokaverkefni sem hluti af

Bachelor of Science-prófi í Hestafræði

Leiðbeinandi: Helga Gunnarsdóttir

Meðleiðbeinandi: Eveliina Aurora Marttisdóttir

Ræktun & fæða

Landbúnaðarháskóli Íslands

Hvanneyri, maí 2025

Íslenskur titill: Lýsandi rannsókn á þremur íslenskum hestum þar sem mældur er munur á lóðréttri ósamhverfu á brokki í beinni línu og í hring með tveimur mismunandi hnakkastaðsetningum með hlutlægu hreyfigreiningarkerfi.
Enskur titill: A descriptive study on three Icelandic horses measuring differences in vertical asymmetry during trot in a straight line and in a circle between two saddle placements using an objective gait analysis system.
10 eininga lokaverkefni sem hluti af Bachelor of Science

Hestafræði
Ræktun & fæða
Landbúnaðarháskóli Íslands
Hvanneyri
311 Borgarnes
Sími: 433 5000

Skráningarupplýsingar:
Maria Kim Desirée Edman, 2025, *A descriptive study on three Icelandic horses measuring differences in vertical asymmetry during trot in a straight line and in a circle between two saddle placements using an objective gait analysis system.* BS ritgerð, Hestafræði, Landbúnaðarháskóli Íslands, 40 bls.

Yfirlýsing

Hér með lýsi ég því yfir að verkefni þetta er byggt á mínum eigin athugunum, er samið af mér og að það hefur hvorki að hluta né í heild verið lagt fram áður til hærri prófgráðu.

Maria Kim Desirée Edman

Abstract

In Iceland, saddles are typically placed more caudally on the horse's back than what is traditionally taught in other disciplines. It is believed to enhance shoulder freedom and overall gait performance, but there is very limited scientific evidence that supports this belief. This study aimed to explore if and how two different saddle positions affect symmetry in trot in three Icelandic horses, using an IMU-based objective gait analysis system (Equi-Pro). Three conditions were used to assess the horses: in-hand without a rider, ridden in a traditional saddle position (P1), and ridden in a more caudal position which is commonly seen in Icelandic horses (P2). Objective data on vertical movement asymmetry (minDiff and maxDiff values) was collected and measured at the head, withers, and sacrum. Additionally, subjective feedback from the rider on the perceived balance, comfort, and overall rideability of the horses was gathered to complement the objective data. Overall, the objective data indicated better symmetry in P1 compared to P2, although the differences between the positions were generally small and varied between the horses. The rider consistently favored P1, reporting better balance, responsiveness, and overall comfort, while noting increased tension, shorter strides, and balance issues in P2. Individual variations between horses, familiarity with P1, and other factors such as differences in training, a shift in saddle position, and measurement delays may have influenced the results. This study suggests that saddle position might affect both symmetry and rideability, although the effects are highly individual. Further research is needed involving larger sample sizes, adaptation periods for saddle positions, repeated measurements, and assessments of physiological stress responses to gain a better understanding of the potential biomechanical and behavioral effects of saddle placement in Icelandic horses.

Keywords: Icelandic horse, saddle position, saddle fit, equine biomechanics, equine locomotion, symmetry, asymmetry, objective gait analysis, inertial measurement unit (IMU)

Acknowledgements

I would first like to thank my supervisor, Helga Gunnarsdóttir for her advice and encouragement throughout this project. I could not have completed this thesis without her support, from performing the objective measurements to providing feedback and reviewing the writing process. I would also like to thank my co-supervisor, Eveliina Aurora Marttisdóttir, who provided horses for the study, trained and rode them during the measurements, as well as ensuring proper saddle fit. I would like to thank Hestamannafélagið Geysir for providing access to the riding arena where the measurements took place and Lára Þorsteinsdóttir Roelfs for assisting throughout the measurement day, and for her help in caring for my horses and supporting me through this project. I would also like to thank Marianna Ósk Mikaelsdóttir for her support, and for motivating me when I felt like giving up. Finally, thanks to everyone who in any way helped or supported me and this project.

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1. Introduction

1.1 Background and study aim

In Iceland, it is common practice to place the saddle more caudally on the horse's back than what is traditionally taught because it is believed to enhance shoulder freedom and gait performance. However, this belief seems largely anecdotal and lacks scientific evidence regarding its biomechanical effects (Ramseier et al., 2013; Waldern et al., 2015). Therefore, there is a clear need for research that examines how variations in saddle placement might affect the biomechanics of Icelandic horses. This study seeks to explore this topic by measuring and comparing the vertical asymmetry at the head, withers, and shoulders, between two different saddle positions, during trot in three Icelandic horses, using an IMU-based gait analysis system. The aim was to investigate if there would be any measurable differences in movement when the saddle is placed more caudally compared to a traditionally taught saddle position. The hypothesis is that placing the saddle more caudally will alter the horse's movement symmetry compared to both movement without a saddle and with a traditionally positioned saddle. In addition, the study aims to explain the function of objective gait analysis systems and their value of use in assessing symmetry in these three horses.

The research question for this study was: *Does the saddle placement affect vertical movement symmetry in Icelandic horses?*

1.2 Equine Biomechanics and locomotion

1.2.1 Basics of equine biomechanics

Equine locomotion refers to the movement of horses and can be studied by the principles of biomechanics. Biomechanics can be split into two fields; kinematics, which describes movement such as stride length and joint angles, and kinetics which is the study of forces behind those movements. English photographer and pioneer of equine biomechanics Eadweard Muybridge used several cameras to take sequential pictures of moving horses in the late 19th century. He was the first to show that there is a moment of suspension during the trot where all four hooves are off the ground. Since then, advances in technology have led to the development of gait analysis systems which allows for objective and precise evaluation of equine locomotion. Kinematics can be studied using cameras, high-speed video, or specialized tracking equipment, while kinetics uses instruments such as force plates and accelerometers to measure the forces that are acting on the limbs (Marlin & Nankervis, 2002).

1.2.2 Phases and symmetry in movement

Locomotion is controlled by a complex interaction between the musculoskeletal, nervous, and the vestibular system (Clayton & Hobbs, 2017). Each cycle of movement has two phases, a stance phase, when the hoof is weightbearing and in contact with the ground, and a swing phase, when the hoof is off the ground and moves forward. The stance phase can further be divided into a deceleration part (impact phase), where the limbs absorb force, and a propulsion part (push-off phase), where it pushes the horse up and forward. During each phase the head, withers, and pelvis experience oscillations that change with each gait. Analysis of stride length, stride duration, and limb coordination is made possible by these stride phases, which also specify the timing and force distribution within the gait cycle (Leach et al., 1984).

Another important feature of locomotion is symmetry, which refers to equal timing and movement between the left and right sides of the body. Symmetrical movement is generally associated with good balance, coordination, and soundness, while asymmetry reflects differences in movement between the sides. Some degree of asymmetry is normal because of individual variations, but significant or sudden changes can indicate discomfort or lameness. In gait analysis systems, symmetry is commonly used to assess balance and identify irregularities (Rehren, 2018). In this study, symmetry was assessed by measuring the differences in the vertical displacement of the head, withers, and sacrum between the diagonals in trot, which in theory should be as symmetrical as possible in a sound horse.

1.3 Equine gaits

1.3.1 Classification

Most horse breeds perform only the four basic gaits; walk, trot, canter, and gallop, while some breeds, like the Icelandic horse, also exhibit additional gaits such as the tölt and pace. Gaits are classified by the sequence and timing of limb movements and whether there are suspension phases, where all limbs are off the ground (Clayton & Hobbs, 2017). The gaits can also be classified into symmetrical and asymmetrical gaits. In symmetrical gaits, the limbs moves synchronized and at equal intervals, either between diagonal limb pairs, such as in the trot, or between ipsilateral limb pairs, as in the pace. These patterns create mirrored limb movements between the right and left side of the body. In contrast, asymmetrical gaits involves uneven timing between the limbs and a different sequence of footfalls on each side, as seen in the canter and gallop (Hildebrand, 1965) for example.

1.3.2 Walk

The slowest gait is the walk, which is a symmetrical gait characterized by a four-beat lateral sequence, meaning that each hoof land on the ground independently. The sequence is as follows: left hind, left front, right hind, right front and there is always two or three hooves in contact with the ground (Robilliard et al., 2007). During the walk, the horse's body moves like an inverted pendulum, as each hoof lands, the part of the body above it (withers for front hooves and croup for the hind hooves) is at its lowest position, then rises to their highest point during midstance, and then lowers again as the hoof comes off the ground. During a stride (a complete cycle of all four legs) the withers and croup alternate their vertical motions, each rising and falling twice, when the withers rise, the croup lowers and vice versa. Additionally, the head moves vertically in phase with the croup and out of phase with the withers (Rhodin et al., 2022).

1.3.3 Trot

The trot is a symmetrical two-beat gait, where diagonal limb pairs move together. Left forelimb and right hindlimb move forward at the same time and the right forelimb and left hindlimb move together. Between beats there is a suspension phase when all limbs are off the ground (Rhodin et al., 2022). Variations of the trot depend on the stride length and speed and include, working, medium, and extended trot, with the collected trot being the slowest and the extended trot the fastest (Back & Clayton, 2013). The horse's body moves in a wave-like vertical motion, with the head, withers, and sacrum rising and lowering simultaneously twice per stride. The withers move in unison with the forelimbs, reaching their lowest point during forelimb impact and their highest point during forelimb push-off, while the sacrum moves with the hindlimbs, being lowest at hindlimb impact and highest at hindlimb push-off. The head has a greater range of motion and, like the withers, aligns its vertical displacements with the forelimb impact and push-off phases (Rhodin et al., 2022). Because of its symmetrical structure and clear diagonal limb pairing, the trot is commonly regarded as the standard gait for measuring movement symmetry and locating asymmetries that might indicate discomfort or lameness.

1.3.4 Canter and gallop

The canter is classified as an asymmetrical three-beat gait, the sequence of footfalls start with the trailing hindlimb (non-leading side), followed by the leading hindlimb and the opposite (trailing) forelimb landing on the ground at the same time, and ends with the landing of the leading forelimb. This leading forelimb initiates the suspension phase, where all hooves are off the ground before the cycle repeats (Robilliard et al., 2007). The gallop is the fastest of the main gaits, and it is similar to the canter but stride length and frequency are maximized. The leading hindlimb contacts the ground just before the trailing forelimb making the gait four-beat (Back & Clayton, 2013).

1.3.5 Tölt

Certain breeds, like the Icelandic horse, can perform ambling gaits such as the tölt, a four-beat symmetrical gait. The footfall sequence is the same as in the walk; left hindlimb, left forelimb, right hindlimb, right forelimb, and does not have any suspension phase, but unlike the walk, the tölt can be performed at higher speeds and there is only one or two hooves on the ground (Biknevicius et al., 2006).

1.3.6 Pace

Some breeds have a gait known as the pace; a symmetrical two-beat gait where ipsilateral limbs move together. The pace has a suspension phase, where all limbs are off the ground, creating a distinctive side-to-side motion. It is commonly seen in gaited breeds such as the Icelandic horse and is typically performed at higher speeds. Pace is associated with homozygosity for the *DMRT3* mutation, which enables lateral limb movement (Robilliard et al., 2007). In pace, the ipsilateral forelimbs and hindlimbs contact the ground at almost the same time, with the hindlimbs landing slightly before the forelimb on the same side, followed by a suspension phase before landing on the opposite lateral pair. At high speeds, the timing difference is more pronounced and the pace becomes four-beat. The hindlimb makes ground contact about 30 milliseconds before the lateral forelimb, which is about 7% of the total stride duration. This dissociation allows for more effective propulsion, as the stance time becomes shorter with increasing speed and without it, there is less time to generate propulsive force before the next limbs strike the ground, which would limit forward momentum (Wilson et al., 1988).

1.4 The Icelandic horse

1.4.1 Gait genetics

The Icelandic horse is known for its additional gaits, tölt and pace. Not all Icelandic horses can pace, and those are known as four-gaiters, while those exhibiting pace are known as five-gaiters. The distinction between these gait types is mainly determined by genetics, and linked to a mutation in the *DMRT3* gene, which is known as the “gait keeper” mutation. This mutation affects spinal cord function and limb coordination. Horses that are heterozygous for the mutation (genotype CA), are typically four-gaited and able to walk, trot, canter/gallop, and tölt, while horses that are homozygous (genotype AA), generally also possess the ability for pace and are classified as five-gaited (Andersson et al., 2012). However, more than 30% of homozygous AA horses are unable to pace and are despite their genetic predisposition to develop it, regarded as four-gaited. This suggests that other genetic or environmental factors influences the expression of gaits (Sigurðardóttir et al., 2023). Some Icelandic horses carry the CC genotype, which means that they do not have the *DMRT3* mutation associated with lateral gaits. Although these horses often can demonstrate tölt, training them to do so tend to be significantly more difficult compared to those with CA and AA genotypes (Jäderkvist et al., 2015)

1.4.2 Gait diversity and what sets the Icelandic horse apart

Most horse breeds are non-gaited which means that they can naturally perform the three main gaits; walk, trot, and canter/gallop. Certain breeds such as the Paso Fino, Tennessee walking horse, and the Icelandic horse can perform one or more additional gaits, such as paso, running walk, tölt, or pace, depending on the breed and these breeds are known as “gaited breeds”. Typically, these gaited breeds are able to perform one additional ambling (four-beat) gait without a suspension phase (Nicodemus & Clayton, 2003). What sets the Icelandic horse apart from traditional three-gaited breeds and other gaited breeds is that they are one of few breeds which can be either four- or five-gaited, depending on if they can pace (Jäderkvist Fegraeus et al., 2017). A study by Staiger et al. (2016), showed that gaited horse breeds tend to have different physical traits compared to non-gaited breeds, such as longer forelimbs and narrower distal limbs, which could influence coordination, stride length, and gait performance. Anecdotal evidence suggests that different gait preferences are associated with specific body conformations. For example, horses performing pace often have longer backs and loins, shorter necks and shorter, steeper hips than those that perform four-beat ambling gaits like running walk or tölt.

1.5 Saddle fit and placement

1.5.1 The importance of saddle fit and placement

A correctly fitting saddle is essential for both the horse and rider and directly affects performance and health. A saddle that does not fit, either the horse or the rider, can affect the horse’s comfort and well-being, causing pain and swelling in the thoracolumbar area, impairing the back function, and lead to long-term muscle atrophy, especially behind the shoulder blade. The horse’s behavior can provide indications of discomfort by a poorly fitted saddle. Abnormal behaviors which may indicate discomfort include flinching, fidgeting or threatening to bite or kick when being groomed and tacked up. For the rider, an ill-fitting saddle could impair the position and balance, as well as causing soreness in the back and hip area. If the seat of the saddle is too wide, it can lead to pain and discomfort under the rider's seat bones. Additionally, if the seat places the rider too close to the front or tilts the rider forward, it can result in soreness or injuries in the perineal area (Dyson et al., 2015).

1.5.2 Saddle fit and placement in relation to the horse

For a saddle to fit it must be balanced on the horse and evenly distribute the rider's weight, ideally 40% of the rider's weight should be in the middle of the saddle and 30% of the weight on the front and back part of the saddle. The middle section should be just above the horse's center of gravity, right behind the withers, where the horse's back is the most stable during movement (Schleese, 2013). The length of the saddle should not go beyond the last thoracic vertebra (T18) since it can negatively affect the function of the gluteus medius muscle, which is essential for hindlimb propulsion and extension, and the iliocostalis muscle, which supports and stabilizes the spine. Additionally, pressure on the lumbar transverse processes, the bony projections to which muscles and ligaments attach, can reduce flexibility in the spine and hinder lateral bending (Dyson et al., 2015). The gullet should make sure there is enough space, about two to three fingers, over and at the sides of the withers to allow for shoulder freedom. The gullet channel width should be consistent throughout the saddle length and avoid contact with the spine, ligaments, and nerve endings. Optimal width is usually between 6 to 10 cm. If the channel is too narrow, movement is restricted and can potentially lead to long-term spinal issues. The tree points and gullet plate should align with the shoulder angles of the horse, to allow the scapula to rotate upward and backwards freely under the saddle (Schleese, 2013).

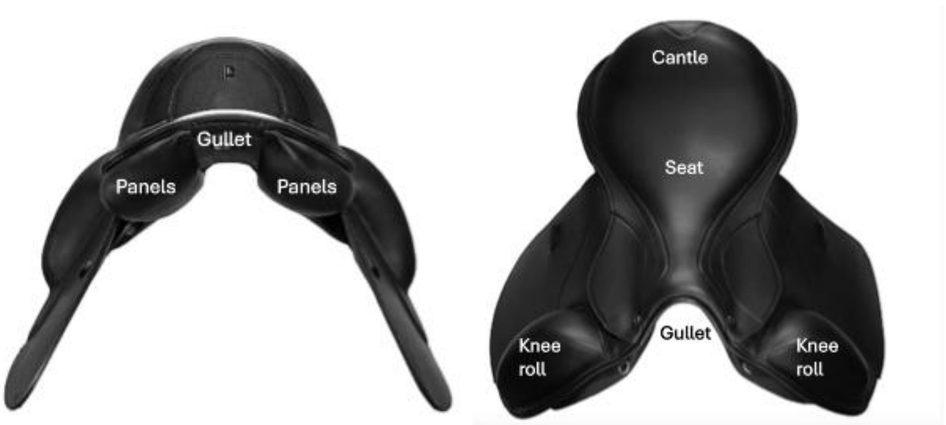


Figure 1: Relevant parts of the saddle. Screenshot taken and edited by the author from Hestbak ehf, accessed May 2, 2025.

1.5.3 Saddle fit for the rider and its influence on the horse

The saddle must also fit the rider, and its design and shape can greatly affect the rider's position, balance, and comfort. A well-fitted saddle helps the rider to sit in a neutral and balanced three-point position, with the shoulder, hips, and heels, aligned in a vertical line. This position is shown in Figure 2 below and enables the rider to follow and influence the movement of the horse efficiently. The rider should sit in the middle of the saddle which is positioned right above the horse's center of gravity. If the saddle is too small for the rider, it restricts the rider's mobility and can lead to tension and pain in the lower back and hips, while a saddle that is too big for the rider, could prevent the rider from sitting balanced in the middle, resulting in excessive movement and instability. When the rider's balance is impaired, it can lead to uneven weight distribution on the horse's back and disrupt the horse's balance as well, potentially causing discomfort and affecting its performance (Williams & Tabor, 2017).

Figure 2. Rider in a neutral three-point seat. Screenshot taken by the author from "Suffering in silence: Exploring the painful truth—the saddle-fit link to physical and psychological trauma in horses" by Schleese, 2013, eBook version.

1.5.4 Traditional Icelandic saddling practices

Traditional Icelandic saddling practices differ from what is typically seen in other equestrian disciplines, aiming to place the rider more caudally on the horse's back because it is believed to enhance shoulder freedom and movement during tölt. Some riders also state that when riding an Icelandic horse in tölt, it requires shifting of the horse's weight toward the hindquarters, as well as raising the head and forehand, which can be achieved by either placing the saddle further caudally on the horse's back, using saddles which are specially made for Icelandic horses where the lowest point of the seat is closer to the cantle, or a combination of both (Ramseier et al., 2013; Waldern et al., 2015).

This has been partially explored by Ramseier et al. (2013), who did a study on 12 Icelandic horses comparing three types of saddles, a traditional Icelandic saddle, a dressage saddle and a treeless saddle. They found that the Icelandic saddle positioned the rider 12 mm more caudal in walk and 15 mm more caudal in tölt compared to the other saddles. This correlated with a slight shift in weight toward the hindquarters, but the forelimb kinematics and stride characteristics did not differ between any of the saddles.

Although Ramseier et al. (2013) provided some data on saddling practices, the biomechanical effects of traditional Icelandic saddling practices remain largely unclear. In a later study, involving the same authors, Waldern et al. (2015), stated that whether, and to what extent, the saddle and/or rider placement affects the biomechanics of the Icelandic horse had not been scientifically proven yet. As of today, research on saddle positioning is limited and many beliefs regarding Icelandic saddling practices seems to be largely anecdotal, suggesting that further research in this area is needed.

1.6 Objective gait analysis systems

In recent years, objective gait analysis systems have been developed and are used to assess asymmetries and locomotion characteristics in horses. They provide measurable data, which can be useful for detecting small changes in symmetry, stride length, or movements that may not be visible to the human eye. Traditional visual assessments vary depending on the observer and are always subjective while these systems give more reliable and repeatable results, which does not mean that the results will be the same each time, but that they will be comparable when used under the same conditions since horse's movements vary between days and measurements. Subtle movement asymmetries can be very difficult to identify and are often missed during visual observations as the human eye lack the precision that is needed to detect small deviations from normal locomotion patterns, especially in cases of minor lameness. These subtle asymmetries can be detected by objective gait analysis systems which makes them invaluable for accurate assessments of equine locomotion (Crecan & Peștean, 2023).

Depending on the technology used, most kinematic analysis systems fall into two main categories, the first being inertial measurement unit systems (IMU), which uses gyroscopes that measure rotation or angular velocity during motion, and accelerometers, which tracks the acceleration of the surface to which they are attached. The accelerometers and gyroscopes are put together in small sensors which are placed on certain anatomical points on the horse and gives a three-dimensional picture of how the horse moves. The other category is optical motion capture systems (OMC), which uses infrared cameras and reflective markers, which bounce light back to the source allowing the cameras to detect their location and track three-dimensional movements. Another newer approach is video-based gait analysis using artificial intelligence, which tracks anatomical points directly from video recordings without using any physical markers. Instead, AI systems are trained on large datasets to identify and follow key anatomical points. These systems analyze movement frame by frame with high accuracy. Each of these gait analysis systems has its strengths and weaknesses depending on where, how, and why it is being used (Feuser et al., 2022). In the following sections, four gait analysis systems from each of the categories will be described in more detail: Equi-Pro, Sleip, Equinosis Q Lameness Locator, and Qualisys (Qhorse).

1.6.1 Equi-Pro and Equinosis Q Lameness Locator (IMU-based system)

Inertial measurement units (IMUs) are small wireless sensors which can be attached to the horse, using adhesive tape, elastic straps, or special sensor pockets, on places such as the head, withers, pelvis, and limbs to measure acceleration forces and angular velocity in three directions; the vertical axis, which measures dorsoventral movement, the longitudinal axis, which measure back and forward motion, and the lateral axis, which measure movement to the sides. Data recorded from all three axes provides a three-dimensional picture of horse's locomotion during walk, trot, or canter (Crecan & Peștean, 2023).

A commonly used IMU-based system is the Equinosis Q Lameness Locator, which as the name suggests, is used to detect and localize lameness in horses. The system involves placing two accelerometer sensors, one on the horse's head and the other on the sacrum, measuring their vertical displacement, and a third sensor, a gyroscope measuring flexion and extension, on the horse's pastern on the right forelimb. The sensors measures vertical acceleration and movement patterns only during trot because there is just one limb sensor. During trot the horse's legs move in diagonal pairs, so by registering when the right forelimb contacts the ground, the system can calculate the timing of footfalls for all four limbs during a stride cycle (Lopez et al., 2021). The data is transmitted to a tablet, which software evaluates vertical asymmetries in the head and pelvic movement between the left and right sides of the horse's body. The system gives a detailed report of the movement patterns and detects when in a stride asymmetries occur, whether it is during impact, mid-stance, or push-off. The Lameness Locator is available in two packages: the Lite Q system, which is designed for light use and indoor evaluations, and the Classic Q system, which is designed for more heavy use, including outdoors and harsher environmental conditions (Equinosis, n.d.).

Equi-Pro is a gait analysis system which uses IMUs to assess movement in horses. The standard system uses seven sensors which are attached to the head, withers, pelvis, and on all four limbs. The sensors measure various aspects of the horse's movement and can detect which gait the horse is in (walk, trot, tölt, canter, or pace), if the horse is on a straight line or a circle and even detects if the surface is soft or hard. The system can assess symmetry in upper-body movement during walk and trot based on vertical motion and displacement. Two times per stride, the head, withers, and pelvis usually have a cyclic up-and-down pattern that is symmetrical in sound horses when moving on straight lines (Inertia Technology, n.d).

The system uses parameters such as minDiff, corresponding to the impact phase during a stride, which shows the difference between the two lowest points of vertical movement and maxDiff, which corresponds to the push-off phase and measures the differences between the two highest points, to measure the symmetry of the horse's movements and a value of 0 means perfect symmetry. For the limb movements, the timing of footfalls, stride duration and the number of strides is recorded. It also measures the swing intensity (amount of limb rotation during swing relative to its duration), duration of the stance and swing phases for each leg, and the proportion of the stride during which the hoof is in contact with the ground. Additionally, the range of motion of the limbs is measured, including protraction, retraction, abduction, and adduction. The data from the sensors are streamed to a gateway device which is connected to a computer and receives and process the data in real time (Inertia Technology, n.d).

1.6.2 Qualisys Qhorse (OMC-based system)

Optical motion capture (OMC) systems are regarded as the state of the art of equine objective gait analysis systems that are based on kinematics. These system uses several high-speed infrared cameras, which track retroreflective markers that are placed on specific anatomical points on the horse. The cameras are set up so that they are precisely aligned with each other and record at the same time, which allows them to detect and track the markers on the horse from multiple angles and recreate a detailed three-dimensional picture of the horse's movements (Lawin et al., 2023). OMC systems are very precise and accurate but they are costly since multiple cameras need to be distributed throughout the testing area to track the markers. This method is typically limited to controlled settings like laboratories or clinics, which reduce the suitability of this method for routine diagnostic use (Crecan & Peștean, 2023).

A well-known OMC system used in equine locomotion analysis is Qhorse, developed by Qualisys. The system uses up to twenty infrared cameras, which track clusters of reflective markers that are placed on the horse’s head, withers, and pelvis. The assessments can be performed both on straight lines and circles. Aside from its high level of accuracy and precision, one of the main advantages of the Qhorse system is that results are available within seconds of recording, and the system displays the data in various ways, from a simple overview to a detailed stride-by-stride asymmetry information (Qualisys, 2021).

1.6.3 Sleip (AI-based video system)

Quite recently, a new markerless kinematic system for objective gait analysis became available for use. One such system is Sleip, which uses artificial intelligence (AI) and video-based pose estimation to track and assess locomotion. Unlike IMU or OMC systems, AI-systems does not require any physical sensors or reflective markers attached on the horse. Instead, the system analyzes footage from video recordings captured with a regular smartphone. Because no equipment is needed except for a smartphone, gait assessments can be performed quickly and remotely (Lawin et al., 2023). The software of Sleip automatically tracks anatomical landmarks, such as head, pelvis, and limb joints, to measure stride length, timing, and symmetry in trot, and it can detect subtle irregularities in their vertical movement on straight lines and circles (Sleip, n.d.).

Compared to high-end OMC systems, Sleip provides less precise results, however recent studies has shown that the results are consistent and comparable when identifying asymmetries in movement. In a study when Sleip was compared to two IMU-based systems, Equinosis Q Lameness Locator and EquiMoves, all three systems showed similar results if the same thresholds were used. Sleip, however, recorded fewer strides since it can only register hindlimb strides when the horse is trotting away from the camera, because when the horse is trotting toward the camera, key anatomical points on the hindlimbs are not visible, preventing the system from accurately tracking and identifying them, but overall, it still performed reliably. Sleip is a cloud-based platform using AI, which system is continuously updating and improving as more video data is collected and available. Over time this ongoing process will allow the system to enhance its accuracy and widen its range of applications (Kallerud et al., 2024).

2. Materials and methods

2.1 Horses

Three Icelandic horses were used in this study: two geldings, Hermann (12 years old) and Svörður (9 years old), and one mare, Nóta (8 years old). It was important that the horses were fully grown and physically mature to minimize the influence of growth-related changes on movement, so only horses older than seven years were selected (Leleu et al., 2004). To reduce individual variations and keep the focus on the saddle placement, the horses were selected based on their similarity in terms of body condition, size, and training level. Additionally, the horses had been trained by the same rider for the past year, except for Hermann, who had a different trainer during the two months leading up to the measurements. While his recent training differed slightly from the other horses, his condition and training level were still considered equivalent.

2.2 Rider and saddles

The rider in this study was an experienced Icelandic horse rider, with over ten years of experience in training horses. She was very familiar with the behavior and movement of the three horses, having trained them regular over the past year. To ensure consistency, the same rider rode all horses in both saddle placements during the test. The rider was also responsible for fitting and positioning the saddles as she is an experienced saddle fitter. After completion of the Saddlefit4Life® online course and gaining extensive practical experience from two professional saddle fitters in Finland, she has worked independently as a saddle fitter in Iceland for the past five years and continues to further her education by attending seminars and keeping up with new research in the field.

In the study, two different saddles were used: the Ihesta Katla was used on Svörður and Nóta, and the Velicea Kristall on Hermann. Under the saddles was a simple cotton saddle pad which was kept in the same place during both saddle positions, as one of the IMU-sensors was attached to the front of the pad. Repositioning of the pad could have altered the placement of the sensor and thus influenced the accuracy and results of the measurements. The saddle fit was assessed for each horse through visual inspection and palpation, and other than adjusting their placement on the horse’s backs, no changes were made to the saddles during the study.

Each horse was ridden in two different saddle positions. In saddle position 1 (P1), the saddle was placed slightly cranial to the last (18th) rib, representing the traditional saddle placement. In the second position (P2), the saddle was placed in a vertical line directly above the caudal edge of the 18th rib and about 8-10 centimeters caudal of the shoulder blade, representing traditional Icelandic saddling practices, where the saddle is placed more caudally on the horse's back.

Figure 3: Saddle position 1. Photo taken by the author.


Figure 4: Saddle position 2. Photo taken by the author.

2.3 Experimental design and data collection

The study took place in an indoor riding arena, to provide a consistent and controlled setting. The Equi-Pro gait analysis system was used to evaluate whether and how different saddle positions affects the locomotion, focusing on the vertical movement symmetry. The Equi-Pro sensors measure the vertical displacement of the head, withers, and sacrum. Two parameters are recorded, minDiff; measuring the difference in vertical impact factor between diagonals, and maxDiff; measuring the difference in vertical height (push-off factor) between the diagonals during each stride. The Equi-Pro system measures in absolute numbers, in millimeters, the difference between impact (landing) and push-off (hoof-off). Negative and positive values of these components refer to either a left limb (negative) or a right limb (positive). These values were compared and analyzed across the three test conditions, in-hand without a saddle, ridden in P1, and ridden in P2. Each horse was assessed in trot, on a straight line and in both directions on a circle.

Before recording, the sensors were attached on the poll, at the withers, sacrum, and on all four limbs, and calibrated by having the horse stand still for a few seconds until the calibration procedure was completed, to allow for accurate tracking. The three horses were measured one at a time in the same way, first trotted in-hand on a straight line, back and forth four times ensuring at least 20 strides per direction and then lunged in both directions for about 1.5

minutes per direction on an approximately 12-15 meters large circle. After the measurement without a saddle and rider, the horse was tacked up and ridden in P1. The rider used a neutral three-point seat, with a light rein contact and kept a consistent working speed trot. The horse was first warmed up in walk and trot on the circle for approximately five minutes before the measurements took place, which was performed in the same way as the in-hand assessment, four passes in trot on a straight line in both directions and 1.5 minutes of trot on the circle in each direction. After completing the measurements in P1, the saddle was positioned to P2, and the same recording procedure was repeated without additional warm-up.

Because of the small sample size and single measurements per condition, inferential statistical analysis was not applied. Instead, the focus was on describing observed patterns and individual variations.

2.4 Equi-pro sensor placement

The horses were equipped with seven body-mounted IMUs. One head sensor was placed in a pocket and attached to the bridle using a hook-and-loop fastener. A withers sensor was attached with adhesive tape, to a girth during the in-hand measurements and to a saddle pad during the ridden measurements. One sensor was attached to the sacrum between the left and right tuber sacrale with adhesive tape. Additionally, four sensors were placed on the limbs. Each sensor was put in a pocket and attached to a brushing boot placed on the cannon bones.

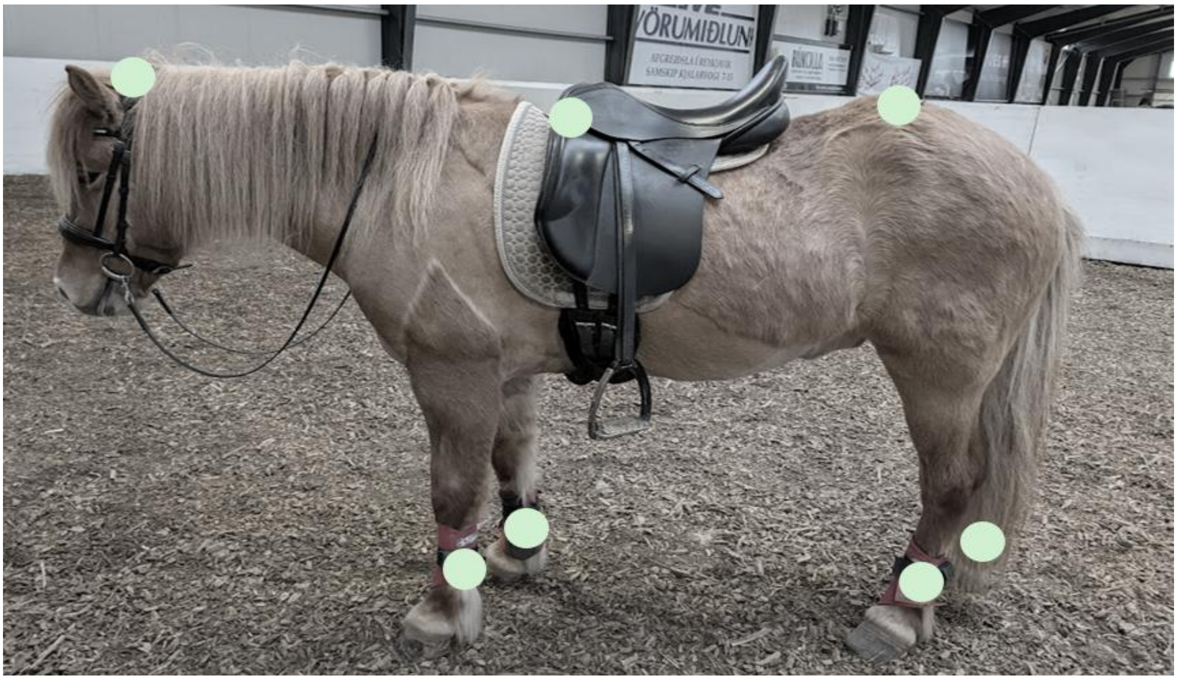


Figure 5: Sensor placement on the horse. Photo taken and edited by the author.

Figure 6: Sensor placement on the head. Photo taken by the author.

Figure 7: Sensor placement on the sacrum. Photo taken by the author.

Figure 8: Sensor placement on the forelimb. Photo taken by the author.

Figure 9: Pocket for the sensor on the limb. Photo taken by the author.

2.5 Rider evaluation and subjective impressions

In addition to the objective gait analysis using the Equi-pro system, subjective comments from the rider were collected to complement the data and add contextual background regarding any observed changes in the horse's locomotion. Since the rider had been training all three horses regularly for the past year, except for one of the horses, which had another rider during the two months leading up to the study, she was very familiar with how they usually moves and behave, which made her feedback especially valuable. After each test ride, the rider was asked to answer a few questions. The purpose was to get her thoughts on how the horses felt in both saddle positions, both when riding on the straight line and on the circle. The following questions were asked:

1. How did the horse feel overall during each saddle position (P1 vs P2)?
   Describe in terms of balance, rhythm, relaxation, and responsiveness.
2. Did the horse feel more comfortable in one saddle position than the other?
   Explain what gave you that impression.
3. How did the horse feel on the straight line in P1?
4. How did the horse feel on the straight line in P2?
5. How did the horse feel on the circle in P1?
6. How did the horse feel on the circle in P2?

7. Could you feel any differences in stride length, impulsion, or connection to the bit between the two saddle positions, either on the straight line or circles?
8. Did you notice any movement of the saddle during any of the rides?
   If so, when and in which saddle position?
9. How did the saddle positions affect your own balance and seat?
10. Is there anything else you would like to mention regarding the horse's behavior, performance, or your own experience during the test?

The rider's responses offered a subjective perspective to the study, providing insight into how variations in the saddle placement might influence not only the horse's locomotion, but also their behavior, comfort, and interaction with the rider.

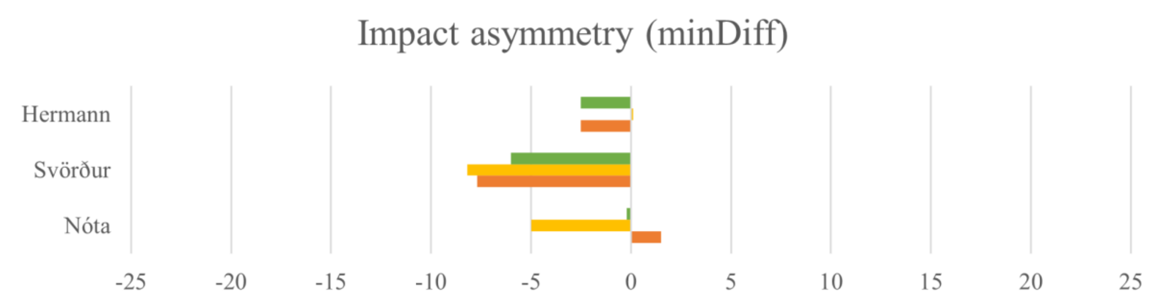
3. Results

3.1 Objective measurements

MinDiff and maxDiff values were measured for the head, withers, and sacrum and the results show how vertical movement asymmetry changed across the three conditions: in-hand without a saddle and rider, ridden in P1, and ridden in P2. The closer the values are to 0, the more symmetrical the horse's movement is, while higher values indicate greater asymmetry between the left and right sides. Summaries for minDiff and maxDiff values for each horse in the two saddle positions are presented in Tables 1,2, and 3 in Chapter 3.1.4.

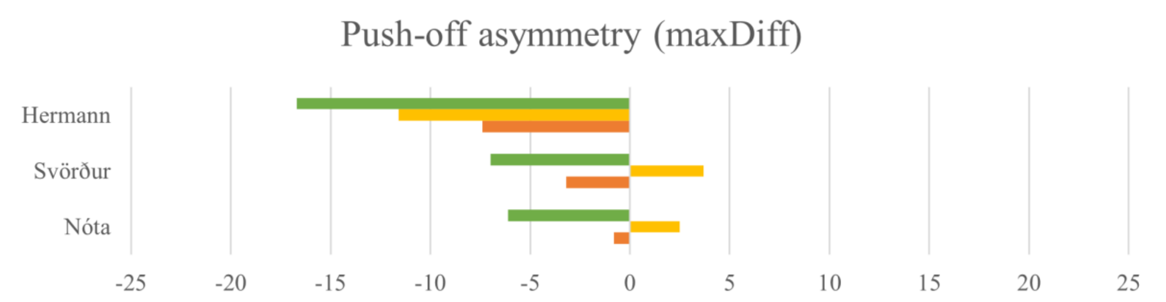
3.1.1 Straight line

For the head all horses displayed minor left-sided asymmetries within normal ranges. Svörður displayed the most left-sided impact asymmetry, while Hermann had the most pronounced left-sided push-off asymmetry. At the withers, Nóta and Svörður showed more right-sided asymmetries, especially Svörður, while Hermann tended to be slightly asymmetric on the left side, except during the in-hand measurement where the left-sided asymmetry was more pronounced during the push-off phase. At the sacrum, all horses displayed a left-sided impact asymmetry, where Nóta had the least asymmetries and showed the largest difference between the two saddle positions, being more symmetrical in P1. During the push-off phase, the results varied more, Hermann displayed a larger right-sided asymmetry during the in-hand test, and minor asymmetries to differing sides when ridden, Svörður consistently showed left-sided asymmetries, which was less when ridden, and Nóta displayed equal right-sided asymmetries without a rider and in P2, while twice as much left-sided asymmetry in P1. Comparing the saddle positions alone, Nóta and Svörður displayed slightly less asymmetries in P2 during both impact and push-off, while Hermann was slightly less asymmetric in P1 during impact and slightly less in P2 during push-off.



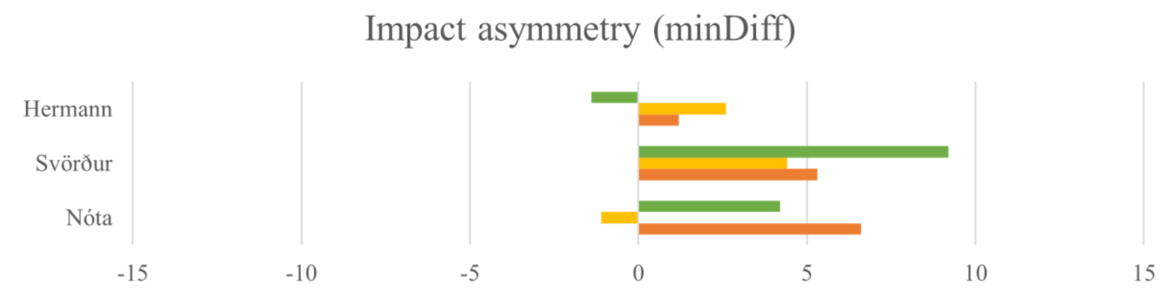
	Nóta	Svörður	Hermann
No saddle	-0.2	-6	-2.5
Position 1	-5	-8.2	0.1
Position 2	1.5	-7.7	-2.5

Figure 10: MinDiff measured at the head on a straight line. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	-6.1	-7	-16.7
Position 1	2.5	3.7	-11.6
Positon 2	-0.8	-3.2	-7.4

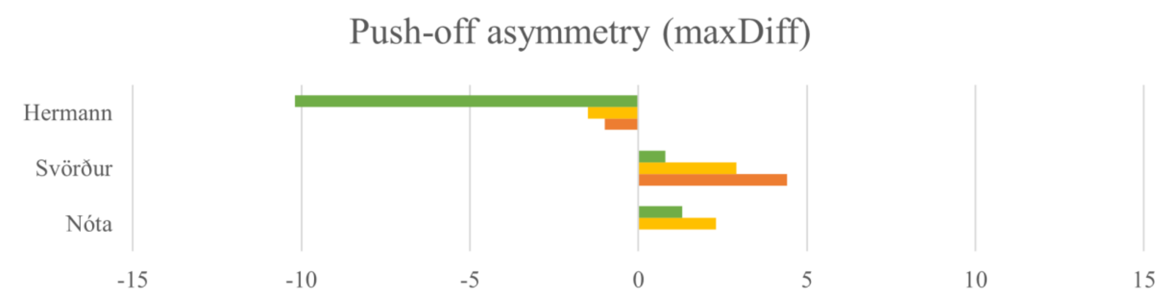
Figure 11: MaxDiff measured at the head on a straight line. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	4.2	9.2	-1.4
Position 1	-1.1	4.4	2.6
Position 2	6.6	5.3	1.2

No saddle Position 1 Position 2

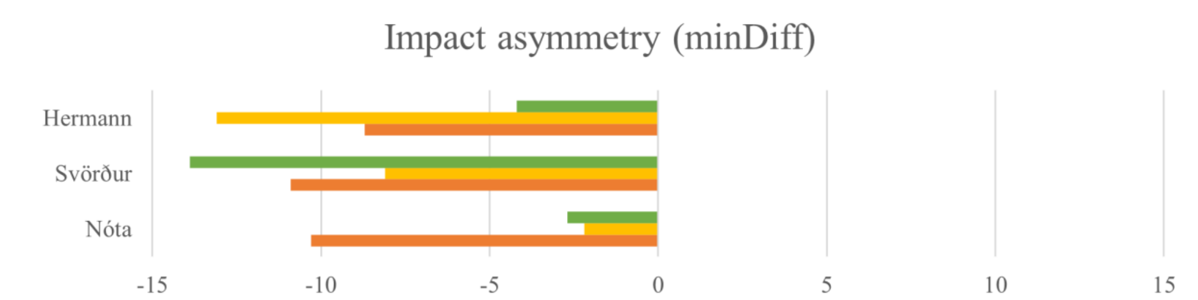
Figure 12: MinDiff measured at the withers on a straight line. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	1.3	0.8	-10.2
Position 1	2.3	2.9	-1.5
Position 2	0	4.4	-1

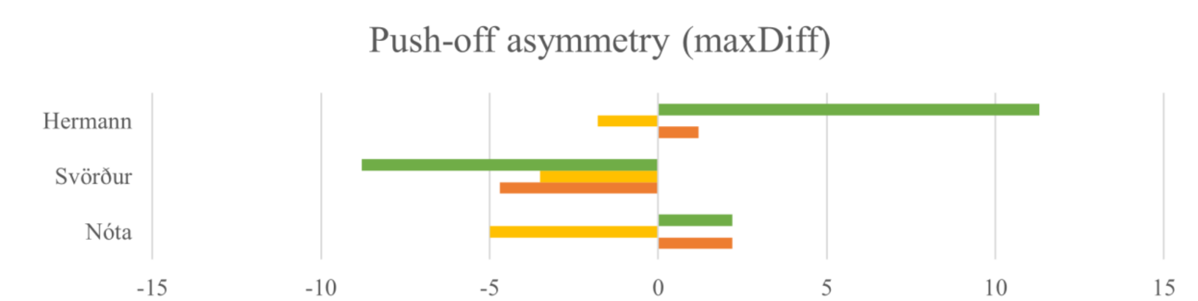
No saddle Position 1 Position 2

Figure 13: MaxDiff measured at the withers on a straight line. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	-2.7	-13.9	-4.2
Position 1	-2.2	-8.1	-13.1
Position 2	-10.3	-10.9	-8.7

Figure 14: MinDiff measured at the sacrum on a straight line. Chart created by the author.

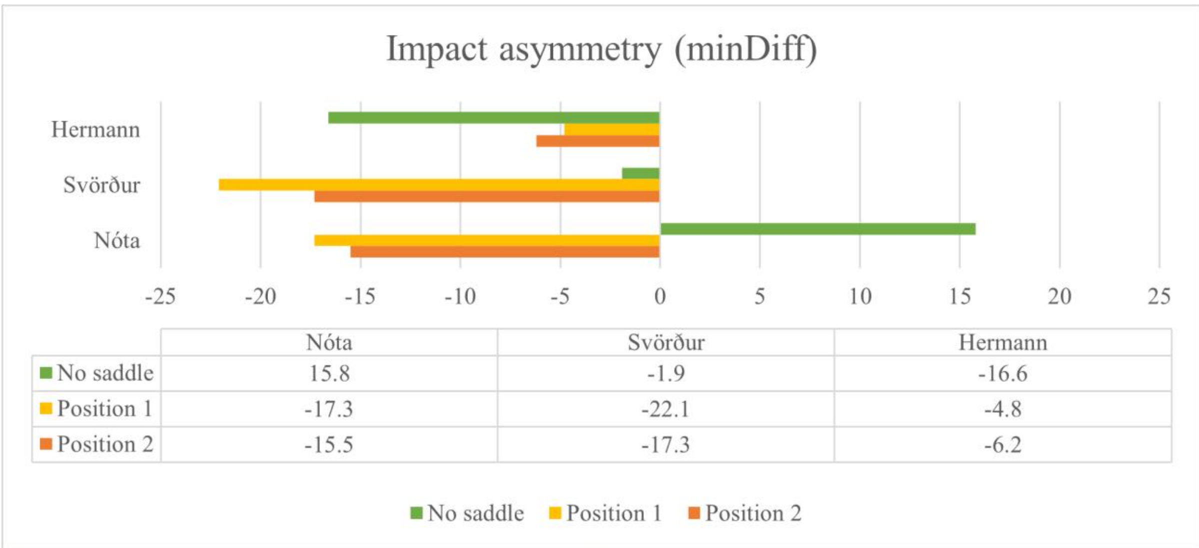


	Nóta	Svörður	Hermann
No saddle	2.2	-8.8	11.3
Position 1	-5	-3.5	-1.8
Position 2	2.2	-4.7	1.2

Figure 15: MaxDiff measured at the sacrum on a straight line. Chart created by the author.

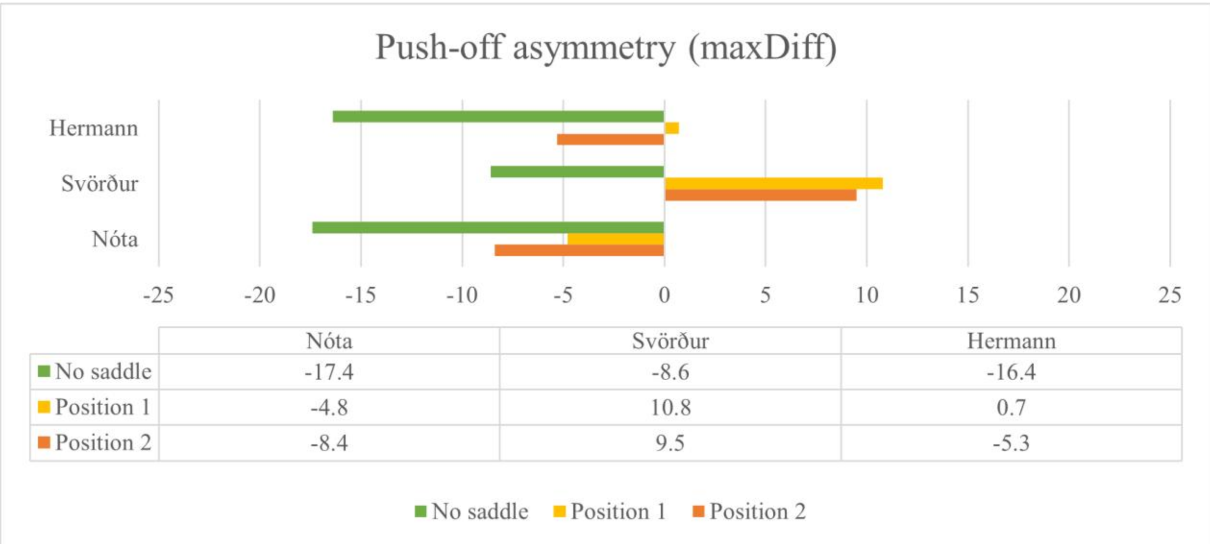
3.1.2 Left circle

On the left circle, the horses generally displayed left-sided asymmetries at the head, except for Nóta during impact in the in-hand measurement and for Svörður in both ridden positions. At the withers, asymmetries tended to be left-sided during impact and right-sided during push-off. Asymmetries at the sacrum during impact showed a clear left-sided pattern across all horses, while the results varied during push-off, Hermann and Nóta showed slight right-sided asymmetries during the in-hand test, and Svörður showed a minor right-sided asymmetry in P2. Comparing the saddle positions, Hermann showed less asymmetries in P1, Svörður in P2, while Nótas results varied depending on stride phase and measurement site.



	Nóta	Svörður	Hermann
No saddle	15.8	-1.9	-16.6
Position 1	-17.3	-22.1	-4.8
Position 2	-15.5	-17.3	-6.2

Figure 16: MinDiff measured at the head on the left circle. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	-17.4	-8.6	-16.4
Position 1	-4.8	10.8	0.7
Position 2	-8.4	9.5	-5.3

Figure 17: MaxDiff measured at the head on the left circle. Chart created by the author.

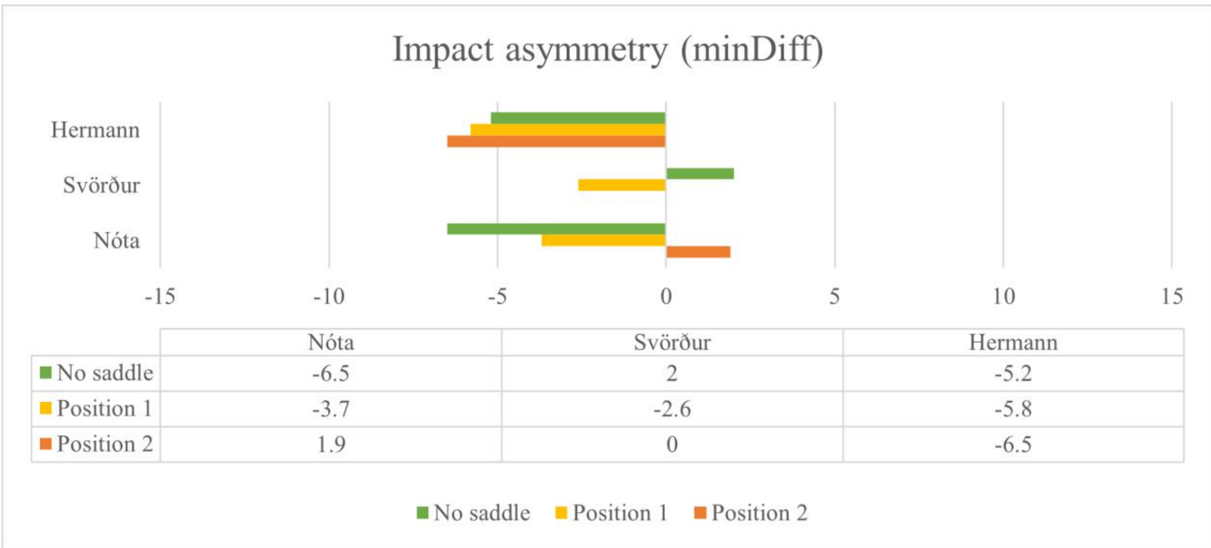


Figure 18. MinDiff measured at the withers on the left circle. Chart created by the author.

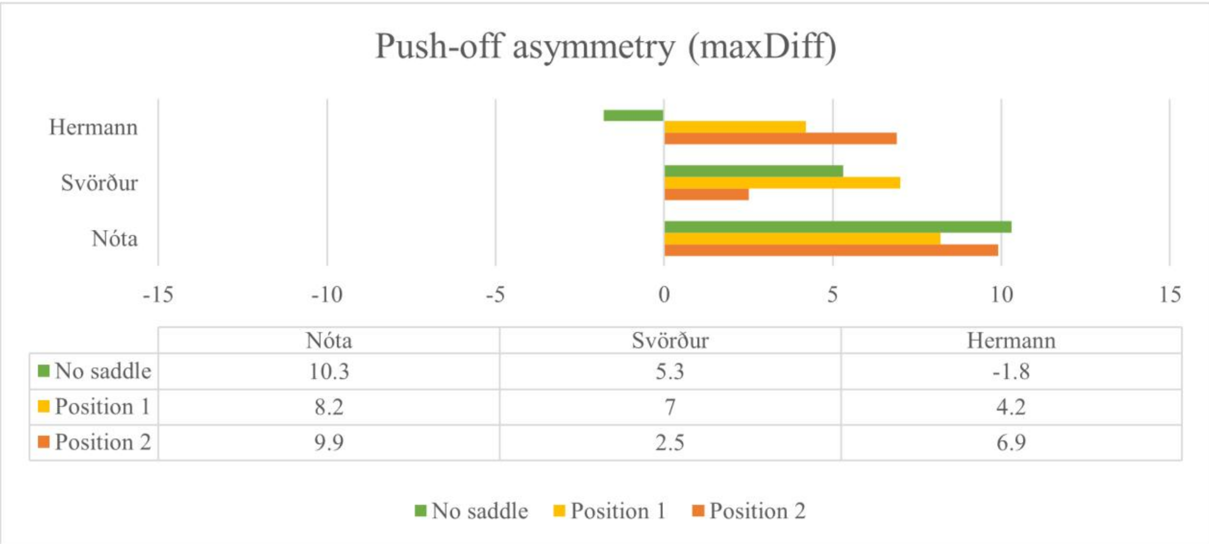
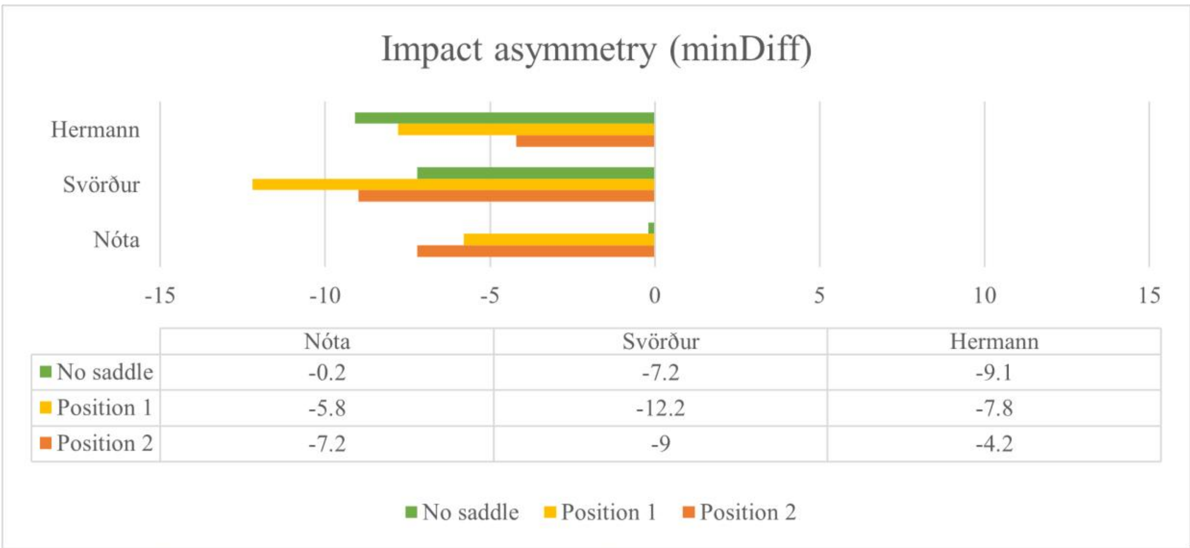
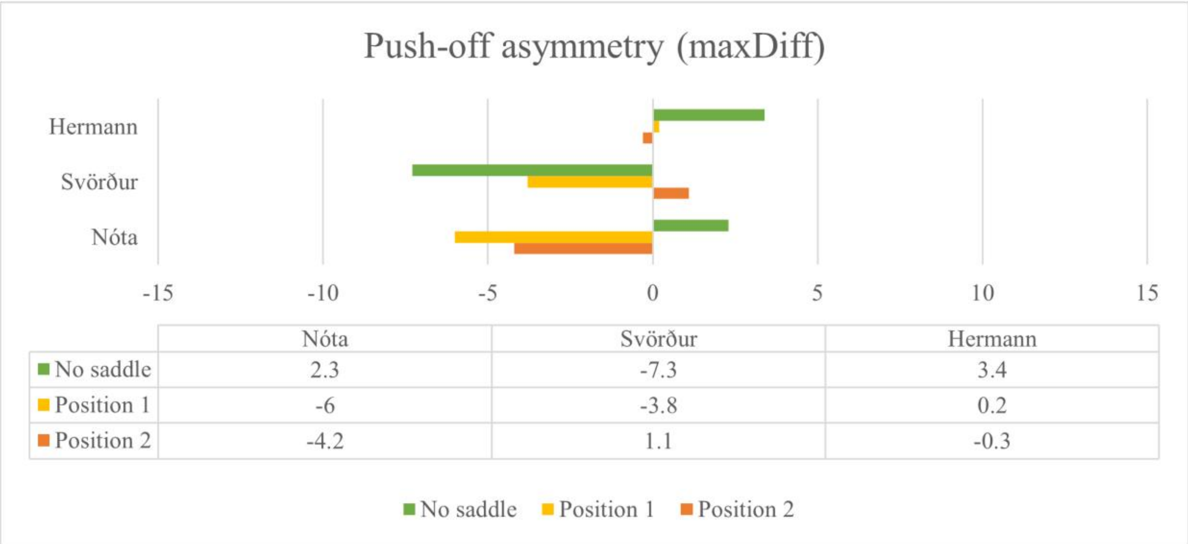


Figure 19. MaxDiff measured at the withers on the left circle. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	-0.2	-7.2	-9.1
Position 1	-5.8	-12.2	-7.8
Position 2	-7.2	-9	-4.2

Figure 20: MinDiff measured at the sacrum on the left circle. Chart created by the author.

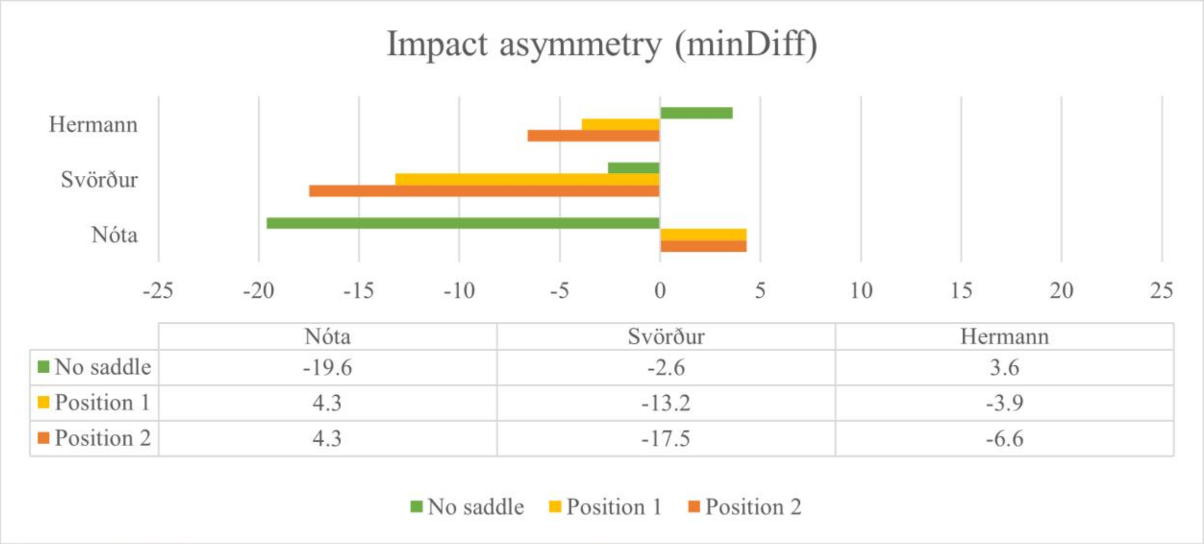


	Nóta	Svörður	Hermann
No saddle	2.3	-7.3	3.4
Position 1	-6	-3.8	0.2
Position 2	-4.2	1.1	-0.3

Figure 21: MaxDiff measured at the sacrum on the left circle. Chart created by the author.

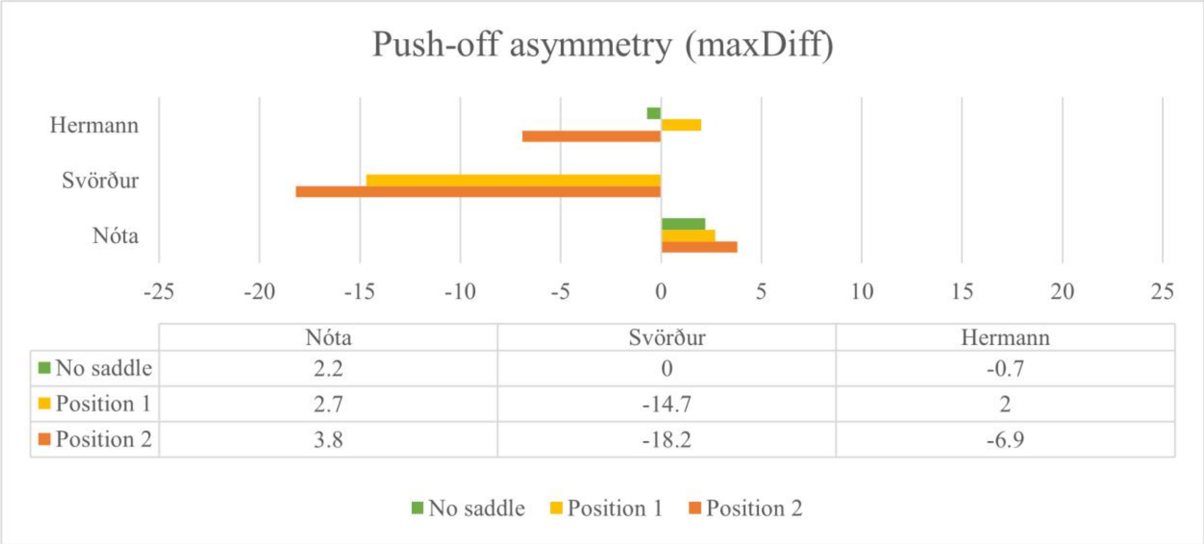
3.1.3 Right circle

On the right circle, Hermann showed left-sided asymmetries at the head in both ridden positions during impact, while showing right-sided asymmetry during the in-hand measurement and slightly greater left-sided asymmetry in P2 during push-off. Svörður showed the greatest asymmetries, which were left-sided except during push-off in the in-hand measurement where he showed symmetrical movement. Nóta tended to show more right-sided asymmetries except in-hand during the impact phase where she demonstrated larger left-sided asymmetries. When comparing saddle positions, all horses generally exhibited less asymmetries in P1 than in P2.



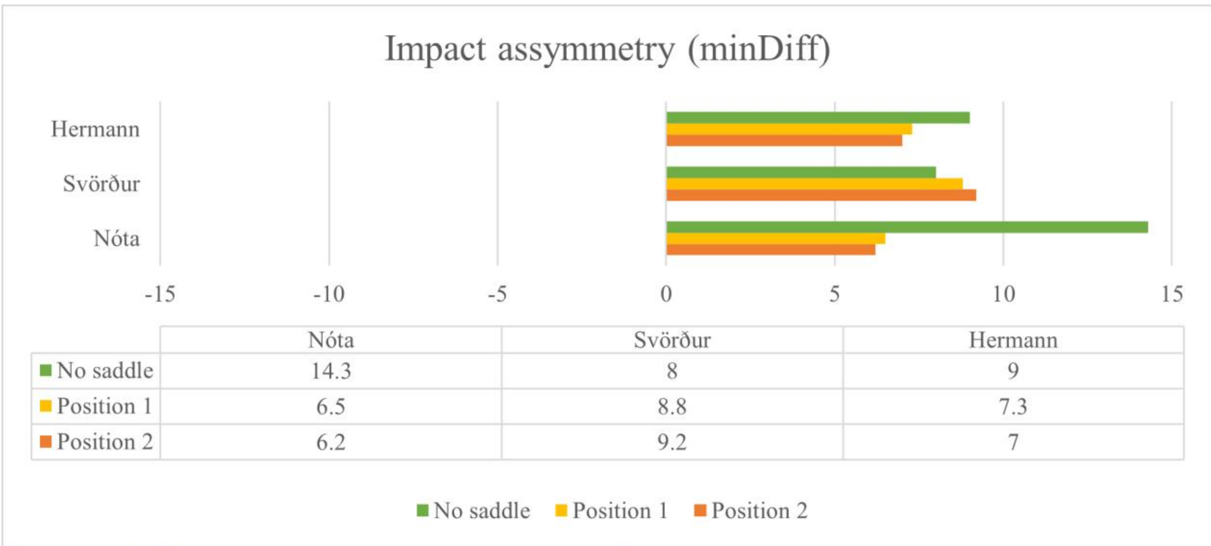
	Nóta	Svörður	Hermann
No saddle	-19.6	-2.6	3.6
Position 1	4.3	-13.2	-3.9
Position 2	4.3	-17.5	-6.6

Figure 22: MinDiff measured at the head on the right circle. Chart created by the author.



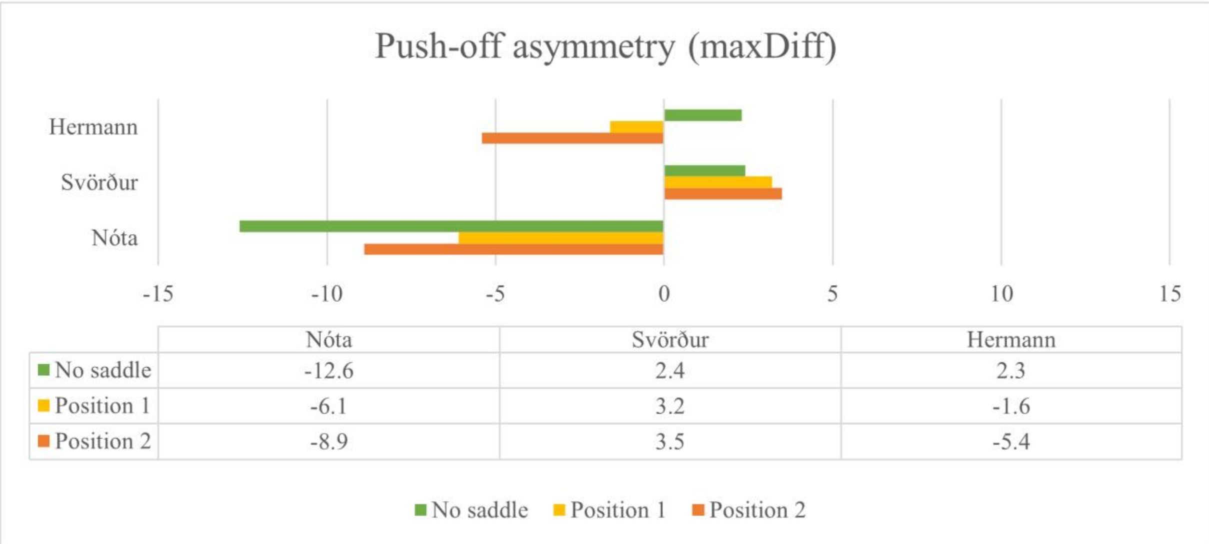
	Nóta	Svörður	Hermann
No saddle	2.2	0	-0.7
Position 1	2.7	-14.7	2
Position 2	3.8	-18.2	-6.9

Figure 23: MaxDiff measured at the head on the right circle. Chart created by the author.



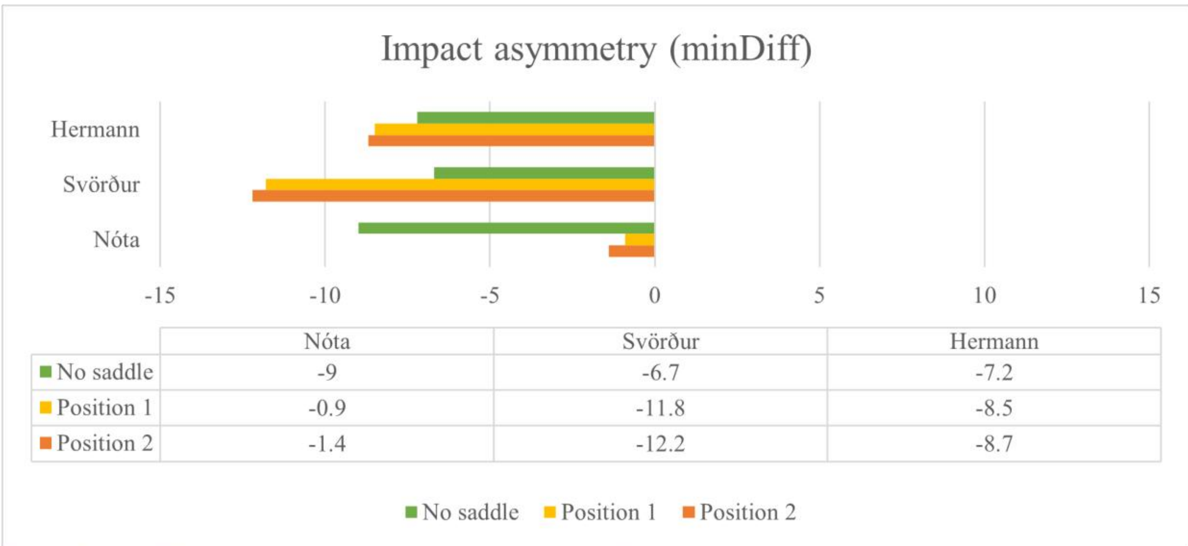
	Nóta	Svörður	Hermann
No saddle	14.3	8	9
Position 1	6.5	8.8	7.3
Position 2	6.2	9.2	7

Figure 24: MinDiff measured at the withers on the right circle. Chart created by the author.



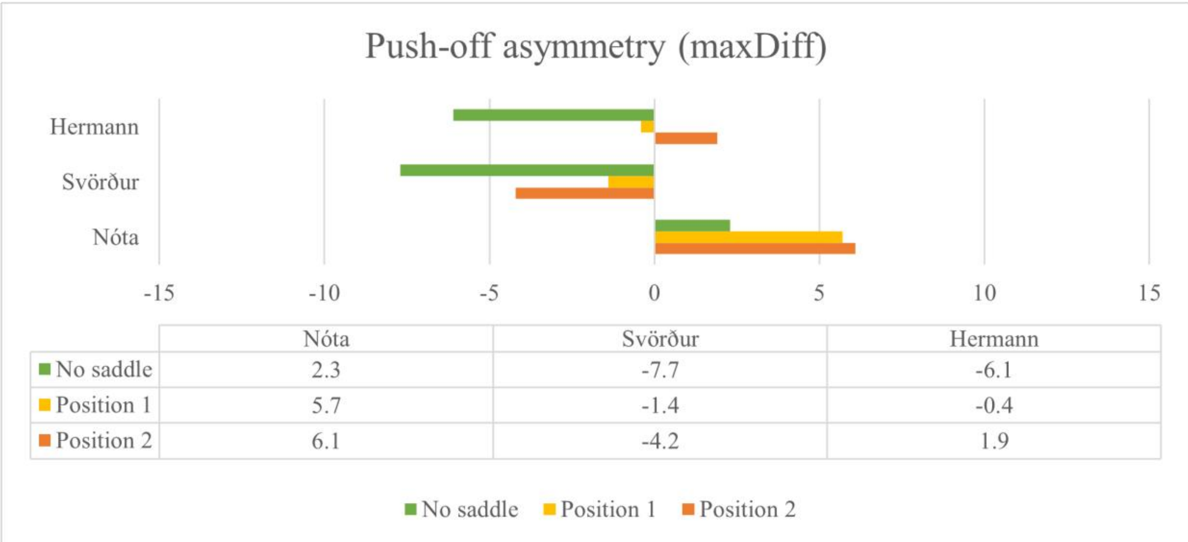
	Nóta	Svörður	Hermann
No saddle	-12.6	2.4	2.3
Position 1	-6.1	3.2	-1.6
Position 2	-8.9	3.5	-5.4

Figure 25: MaxDiff measured at the withers on the right circle. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	-9	-6.7	-7.2
Position 1	-0.9	-11.8	-8.5
Position 2	-1.4	-12.2	-8.7

Figure 26: MinDiff measured at the sacrum on the right circle. Chart created by the author.



	Nóta	Svörður	Hermann
No saddle	2.3	-7.7	-6.1
Position 1	5.7	-1.4	-0.4
Position 2	6.1	-4.2	1.9

Figure 27: MaxDiff measured at the sacrum on the right circle. Chart created by the author.

3.1.4 Summary tables for P1 and P2

Hermann

Table 1. Summary of minDiff and maxDiff values comparing saddle positions 1 and 2 for Hermann. Table created by the author.

Region	minDiff P1 (mm)	minDiff P2 (mm)	maxDiff P1 (mm)	maxDiff P2 (mm)
Head, straight	0.1	-2.5	-11.6	-7.4
Head, left circle	-4.8	-6.2	0.7	-5.3
Head, right circle	-3.9	-6.6	2	-6.9
Withers, straight	2.6	1.2	-1.5	1
Withers, left circle	-5.8	-6.5	4.2	6.9
Withers, right circle	7.3	7	-1.6	-5.4
Sacrum, straight	-13.1	-8.7	-1.8	1.2
Sacrum, left circle	-7.8	-4.2	0.2	-0.3
Sacrum, right circle	-8.5	-8.7	-0.4	1.9

Svörður

Table 2. Summary of minDiff and maxDiff values comparing saddle positions 1 and 2 for Svörður. Table created by the author.

Region	minDiff P1 (mm)	minDiff P2 (mm)	maxDiff P1 (mm)	maxDiff P2 (mm)
Head, straight	-8.2	-7.7	3.7	-3.2
Head, left circle	-22.1	-17.3	10.8	9.5
Head, right circle	-13.2	-17.5	-14.7	-18.2
Withers, straight	4.4	5.3	2.9	4.4
Withers, left circle	-2.6	0	7	2.5
Withers, right circle	8.8	9.2	3.2	3.5
Sacrum, straight	-8.1	-10.9	-3.5	-4.7
Sacrum, left circle	-12.2	-9	-3.8	1.1
Sacrum, right circle	-11.8	-12.2	-1.4	-4.2

Nóta

Table 3. Summary of minDiff and maxDiff values comparing saddle positions 1 and 2 for Nóta. Table created by the author.

Region	minDiff P1 (mm)	minDiff P2 (mm)	maxDiff P1 (mm)	maxDiff P2 (mm)
Head, straight	-5	1.5	2.5	-0.8
Head, left circle	-17.3	-15.5	-4.8	-8.4
Head, right circle	4.3	4.3	2.7	3.8
Withers, straight	-1.1	6.6	2.3	0
Withers, left circle	-3.7	1.9	8.2	9.9
Withers, right circle	6.5	6.2	6.1	-8.9
Sacrum, straight	-2.2	-10.3	-5	2.2
Sacrum, left circle	-5.8	-7.2	-6	-4.2
Sacrum, right circle	-0.9	-1.4	5.7	6.1

3.2 Rider feedback

The rider reported that there were noticeable differences between the saddle positions regarding the horse's behavior and rideability. In general position 1 was perceived as more balanced and comfortable for both the rider and horses, while in position 2 the rider felt it was more difficult to follow the horse's movements, leading to uneven rhythm, rein connection, and increased tension. Additionally, the rider felt the horses were less responsive to the aids in position 2 compared to position 1. The rider commented that the horses felt very much like they usually do in position 1, except that they were slightly tense, most likely due to the unfamiliar environment. On the circle in position 1, the horses felt "normal" (responsive, rather balanced and no discomfort or tension), although Hermann was noted to be somewhat stiff. In position 2, it was difficult to bend the geldings on the circle, and Hermann in particular was unresponsive to the leg aids and had difficulties maintaining the trot. The rider also mentioned that the rein connection felt unsteady and the movements unbalanced on both horses. Nóta initially felt tense and stiff while taking shorter strides in position 2 according to the rider, however, after a few circles, she became more supple and felt almost the same as in position 1. This change could very likely be related to the saddle sliding forward during the ride, which was noticed after the measurements. The rider reported feeling balanced and able to effectively use the aids in position 1, while maintaining balance and applying aids was more difficult and required more effort in position 2. Additionally, the rider mentioned that Herman seemed to want to run off at one point in position 2, which was interpreted as a possible reaction to tension and discomfort.

4. Discussion

This study investigated differences in vertical asymmetry between two saddle placements by measuring minDiff and maxDiff values in three horses during trot, both in a straight line and on circles. Although no formal veterinary examination was conducted before the measurements took place, the horses were thought to be sound and considered not lame at the time based on the absence of observable signs of lameness. It is important to note that even horses that are presumed to be sound may present mild lameness upon clinical assessment, and it is possible that some of the asymmetries observed in this study might be influenced by undiagnosed mild lameness. This was demonstrated in a study by Dyson & Greve (2016), which evaluated 57 sports horses in active work, assumed to be sound by their owners and found that approximately 75% of these horses were classified as lame when examined by experienced clinicians.

While there were small variations observed between the two saddle positions, the results varied between horses and showed no clear overall pattern. The objective measurements showed only a slight advantage for the traditional saddle position (P1) overall, although the rider expressed a much greater preference for it. This subjective preference could be partly explained by the fact that both the rider and the horses were primarily familiar with P1. In daily training, the rider exclusively uses P1, and the horses as well has exclusively been ridden in this position, which is likely to have influenced their comfort and thus the results.

The objective measurements showed that P1 resulted in slightly better movement symmetries, all things considered, although the results varied between the horses. A study by Hardeman et al. (2019) demonstrated that variations within horses are typically small, while between-horse variations tend to be larger. Variations between horses are influenced by factors such as anatomical differences, training effects, and environmental conditions, such as the surface type and whether moving on a straight line or a circular or bent track. The variations observed between horses in this study likely reflect individual differences like those described by Hardeman et al. (2019).

The asymmetry values in this study tended to be greater on the circles than on the straight lines which was expected due to the so-called “circle effect”. This effect has been described in previous studies (Clayton & Sha, 2006; Hardeman et al., 2019; Rhodin et al., 2016) and is a consequence of movement on a curved path, characterized by natural asymmetries in limb loading and movement when the horse moves on a circle compared to a straight line. The circle has a gravitational effect, causing the horse to lean to the inside, to be able to stay on the circle. That causes the horse to load the limbs differently and change the impact (minDiff) and push-off (maxDiff) values in comparison with the straight line. A study investigating asymmetries during lungeing in trot by Rhodin et al. (2016) showed that vertical movements in the head and pelvis were more asymmetric in trot on a circle than on straight lines, and common asymmetry patterns included greater upward movement during push-off of the outside forelimb and reduced downward movement during impact of the inside forelimb for the head and less upward movement during push-off of the outside hindlimb as well as less downward movement during impact of the inside hindlimb for the pelvis. The fore- and hindlimb asymmetries were of similar magnitude but their direction reversed between lungeing directions. The vertical asymmetries for the forelimbs tend to be more inconsistent, since the head can move in a more diverse and complicated pattern than the hindlimbs on the circle. When the left and right directions were compared, less than half of the 201 horses used in the study displayed the same asymmetry pattern in both directions. It was not known whether these differences between the directions were related to pain or a result of natural individual variation, such as handedness of the horses or asymmetries in handling and riding practices (Rhodin et al., 2016).

The horses in this study showed individual variations when compared to common asymmetry patterns that are seen in circles described in the study by Rhodin et al. (2016). Svörður was rather inconsistently following the expected patterns in either saddle position. Hermann's asymmetry patterns aligned slightly more often, especially in P1, though the asymmetry patterns varied. Nóta's asymmetry patterns were varied and often the opposite of the expected pattern. The different saddle positions seemed to have a minimal effect on whether the horses followed the expected asymmetry patterns.

Older studies have proposed thresholds above which asymmetries might indicate lameness, suggesting >6 mm for the head and >3 mm for the pelvis during trot on straight lines. Later studies however found that many sound horses exceed these thresholds, especially for the pelvis. Pfau et al. (2018) proposed revised thresholds of >14.5 mm for the head and >7.5 mm for the pelvis. The horses in our study generally stayed below these revised thresholds on the straight line, especially for the head. In the sacrum, it was only Nóta who consistently remained below the 7.5 mm threshold in all but one instance. On the circle, the asymmetries were more varied and often larger, as expected because of changes in movement and limb loading. Although some asymmetry values in this study were higher than the suggested thresholds by Pfau et al. (2018), they are not necessarily indicating lameness since this was not a clinical lameness assessment and asymmetry can be influenced by several factors such as movement on the circle, rider effects, individual variation between horses, and possible inconsistencies in the sensor placements. However, it is important to take into consideration that Icelandic horses are smaller than the Warmblood horses used in these studies and thus have a smaller range of movement.

The comments from the rider provided a subjective perspective complementing the data. The rider stated that for both her and the horses, P1 provided better balance, reactions, and comfort, while experiencing increased tension, shorter strides, and a reduced balance in P2. The rider commented that in P2 both Svörður and Hermann had difficulties maintaining balance on the circle and were pulling on the reins. Hermann was also grinding the teeth, which could all potentially be signs of discomfort or imbalances. These behavioral signs could be influenced by the horse's unfamiliarity with P2, rather than the saddle position alone.

At the beginning of the measurements in P2, Nóta was reported lacking balance and rein contact but gradually improved and at the end of the measurements the horse felt balanced, content, and similar as to how she felt in P1. This improvement could be associated with the saddle shifting forward, approximately 3-4 cm, during the ride, which moved it closer to the P1 position. In some instances, P1 and/or P2 showed better symmetry compared to the in-hand condition without a saddle and rider, suggesting that the rider and saddle may improve balance and coordination leading to more symmetrical movement.

4.1 Study limitations and considerations for future research

The limitations of this study include the small number of horses, lack of repeated measurements and randomized crossover design where the horses would be ridden in both saddle positions in a random order. While a larger study sample was planned, unforeseen practical challenges and scheduling difficulties limited the number of horses participating. Because of these factors, statistical analysis and comparisons were not suitable and the results should be interpreted as descriptive observations.

There was a significant delay of approximately 40 minutes between the two saddle position measurements for Svörður due to technical issues, which could potentially have influenced the results in P2. Additionally, Hermann's results and behavioral responses might have been influenced by the fact that he had a different trainer the last months before the study. The horses in this study were not particularly used to being ridden in P2, which possibly contributed to the tension and asymmetries observed. The rider's limited experience using P2 likely influenced the subjective evaluation as well as the objective measurements, since riders and horses develop muscle memory and balance based on their usual equipment and positioning, and sudden changes can momentarily affect balance, comfort, and movement (Clayton et al., 2023).

Additionally, the sensor on the withers were attached to the saddle pad and not directly to the skin which might have shifted the position of the sensor and thus affected the results.

In this study, no veterinary lameness evaluation was conducted prior to the study, and future studies should ensure that all horses are evaluated by an experienced veterinarian to rule out any lameness or conditions which could influence symmetry measurements.

Future studies should also include a larger study sample, adaptation periods for each saddle position, repeated measurements, use a rider or multiple riders who are equally familiar with both saddle positions or include an adaption period reducing rider bias, and observe and correct saddle movement during tests avoiding issues like with Nóta. Additionally, measuring physiological responses, like heart rate and cortisol levels, could provide insight into how the saddle position might affect not only the locomotion but also the comfort and overall welfare.

Existing research on the effects of saddle placement in horses is limited, and to date, there have been no previous studies in Iceland which explores how different saddle positions might affect movement symmetry and biomechanics in Icelandic horses. This study, despite its many limitations, hopes to bring attention to this gap and inspire future, more comprehensive research on these effects in Icelandic horses.

5. Conclusions

Based on these results, a traditional saddle placement offers slight advantages in symmetry and especially rider feel, but the effect of saddle placement varies between horses and can be influenced by several factors such as how familiar the horse is with the saddle position and the riders balance and riding technique. Although only three horses were used in this study, clearer and more consistent results between the positions were expected. P2 may potentially cause some welfare problems, especially since it places the saddle behind the last rib, which might affect the horse's comfort and biomechanics by putting pressure on the lumbar region. The rider's perception of the horses being more tense and unbalanced in P2 suggest that this placement is at least not suitable for all horses. The study suggests that although symmetry and rideability can be influenced by the saddle position, the results are very individual. Further research involving more horses, more measurements, and longer adaptation periods are needed to validate and expand on these findings. To better understand how different saddle placements might affect the horse's overall comfort and well-being it would be beneficial to include physiological measurements, such as heart rate, cortisol levels or other stress indicators. While the results are limited by the small sample size and single measurements, the study provided some initial observations on how saddle placement might affect equine locomotion and comfort. Hopefully, future research will continue to explore this topic to improve both horse welfare and performance.

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