Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

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- possible associations between training regimen and locomotion asymmetry

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Degree project • 30 credits
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Department of Anatomy, Physiology and Biochemistry
Agricultural Science program – Animal Science
Uppsala 2023

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Credits:	30 credits
Level:	Master
Course title:	Degree project in Animal Science
Course code:	EX0562
Programme/education:	Agriculture Science program – Animal Science
Year of publication:	2023
Online publication:	https://stud.epsilon.slu.se

Keywords:	training regimens, equisense, locomotion asymmetry, riding horses, lameness locator

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Abstract

Lameness remains a significant welfare concern in riding horses, with over 50% of documented equine injuries attributed to this condition. The precise quantification of training activities and the objective assessment of asymmetry can contribute substantially to our comprehension of the impact of training on injury occurrence and overall performance in riding horses. This pilot study aimed to document the training routines of 24 riders with 29 horses over an 8-week period. The horses used in the study were used for either dressage (n=15), show jumping (n=5), or all-round riding (n=9). They underwent weekly assessments of locomotion asymmetry on both hard and soft footing using the Lameness Locator sensor-based system. As a measure of total asymmetry, vector sums (VS) where calculated for both front and hind limbs, respectively. Activities during training sessions were registered using an inertial measurement unit (Equisense), attached to the saddle girth and connected to a smartphone application, which detected gaits and quantified time spent in each gait.

In the overall horse population, a normal training week (n=139 weeks) consisted of an average (±std) of 5.0±1.4 sessions, with 4.0±1.4 days in the arena and 1.0±1.0 days spent hacking. No significant differences were observed between disciplines in terms of the number of training sessions or sessions performed on an arena. An average training session (n=663) lasted 42±9 minutes, comprising 25±8 minutes of walk (~58% of the duration), 11±4 minutes of trot (~26%), and 7±3 minutes of canter (~16%). The distribution of gaits within training sessions varied according to discipline. Dressage horses trotted more (12±1 minutes) than allround horses (9±1 minutes, $P<0.01$), cantered less (5±1 minutes) compared to both show jumping horses (8±1 minutes, $P<0.05$) and allround horses (8±1 minutes, $P<0.01$). Dressage horses also exhibited greater locomotion asymmetry in their front limbs (VS: 10.45±0.68) than all-round horses (VS: 8.34±0.78, $P<0.05$). A weak positive correlation ($r=0.165$, $P<0.01$) emerged between increased trotting during training sessions and heightened asymmetry, suggesting that horses subjected to more trotting displayed greater asymmetry. Locomotion asymmetry fluctuated between weeks, with elevated VS for front limbs during weeks 5, 6, and 7, and elevated VS for hind limbs during weeks 3, 5, and 7 compared to other weeks ($P<0.05$).

The diverse training regimens observed across horse groups participating in different disciplines indicate that a considerably more extensive study could yield insights into the correlation between training session composition and asymmetry development. However, accurate registrations necessitate a reliable, user-friendly device, and rider compliance is essential. The intriguing variation in locomotion asymmetry warrants further investigation to delineate the normal range of variation in different disciplines and elucidate how training practices contribute to locomotion asymmetry.

Keywords: training regimens, equisense, locomotion asymmetry, riding horses, lameness locator

Sammanfattning

Hälta är en betydande välfärdsfråga för ridhästar, där över 50% av dokumenterade skador hos hästar är på grund av hälta. För att öka förståelsen av hur träning kan påverka utvecklingen av skador samt prestationen hos ridhästar behövs kvantitativa träningsdata och objektiva registreringar av rörelseasymmetri. En pilotstudie utfördes med ett syfte att registrera träning från 24 ryttare med 29 hästar under åtta veckor. Hästarna i studien användes antingen för dressyr (n=15), hoppning (n=5) eller allroundridning (n=9). De genomgick veckovisa bedömningar av rörelseasymmetri på både hårt och mjukt underlag med hjälp av det sensorbaserade systemet Lameness Locator. Vektorsummor (VS) beräknades för både fram- och bakben för att mäta total asymmetri. Träningssessioner registrerades med hjälp av en inertial measurement unit (Equisense). Sensorn fästes vid sadelgjorden och anslöts till en smartphone-applikation som detekterade gångarter och kvantifierade tid spenderad i varje gångart.

En normal träningsvecka (n=139) innehöll ett medel (±std) av 5,0±1,4 träningspass, med 4,0±1,4 dagar på ridbana och 1,0±1,0 dagars uteritt. Det fanns inga skillnader mellan de olika disciplinerna i detta avseende. Ett ridpass (n=663) varade i medel i 42±9 minuter och innehöll 25±8 minuter skritt (~58% av ridpasset), 11±4 minuter trav (~26%) och 7±3 minuter galopp (~16%). Disciplin påverkade distribueringen av gångarter under ett ridpass, där hästarna som användes till dressyr travade mer (12±1 minuter) än allroundhästarna (9±1 minuter, P<0,01), och galopperade mindre (5±1 minuter) än både hopphästarna (8±1 minuter, P<0,05) och allroundhästarna (8±1 minuter, P<0,01). Hästarna som användes till dressyr uppvisade större frambensasymmetri (VS:10,45±0,68) än hästarna som användes för allroundridning (VS:8,34±0,78, P<0,05). Det fanns också en svag positiv korrelation (r=0,165, P<0,05) mellan mer trav och en större rörelseasymmetri, vilket betyder att hästar som travades mer rörde sig något mer asymmetriskt. Rörelseasymmetrin varierade mellan veckor där hästarna vecka 5, 6 och 7 uppvisade större asymmetrier i frambensrörelserna, och under vecka 3, 5 och 7 uppvisade större asymmetrier i bakbensrörelserna.

Variation i träningsupplägg mellan disciplinerna indikerar på att resultat från en större grupp skulle kunna ge information kring korrelationen mellan upplägget av ett ridpass och utvecklingen av asymmetri. För att få korrekta mätningar krävs dock en pålitlig och användarvänlig sensor samt ett stort engagemang från ryttarna. Variation i rörelseasymmetri är intressant och det behövs mer forskning för att få en bild av vilken variation som är normal inom olika discipliner och hur variation i träning påverkar variation i rörelseasymmetri.

Nyckelord: träningsupplägg, equisense, rörelseasymmetri, ridhästar, lameness locator

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Introduction

In Sweden half a million people practise some form of horse riding. Almost 400 000 competition starts were made during 2016. Out of these show jumping is the most common discipline and represents 75% of the competition starts, dressage represents 22%, eventing 2% and other disciplines 1% (Ridsportförbundet, 2018).

The general goal with training of riding horses is to enhance the performance level while maintaining the physical and mental health of the horse (Murray *et al*., 2010). Yet, lameness is a welfare concern in horses used for riding today (Egenvall *et al*., 2006) and represents over 50% of all claims (Agria, 2018). Many factors could lead to lameness; non-optimal training regimens is likely one of these factors (Murray *et al*., 2010). It has earlier been shown that management and training of horses have a great impact on the horses' health (Murray *et al*., 2006), but there is little knowledge about the actual effects of various training regimens (Egenvall *et al*., 2013). To evaluate how horses are trained, and how different training regimens affects horse health, are therefore of great importance. Studies on these subjects have been made but mostly on a low scale or using more subjective evaluation of the training. There is a need for more material including objective data of both training and lameness during a long-term perspective (Eisersiö *et al*., 2015).

Lameness can be defined as increased locomotion asymmetry (Keegan, 2007). Asymmetries can be measured with sensor systems that measure vertical movement of head and pelvis. With these systems even low-grade motion asymmetries can be detected. But even if a horse shows an asymmetric movement, it is not known if the asymmetry is induced by pain or not (i.e. is a lameness), and small levels of asymmetry are considered within the normal range (Rhodin *et al*., 2016). Asymmetry in the locomotion of horses is considered as a factor that affects orthopaedic health negatively (Rooney, 1977).

To increase understanding of how training impacts injury development and performance, quantitative registration of training is necessary. The aim of this study was to collect objective recordings of training and locomotion asymmetry over time. These recordings would then be used to analyse differences in training regimens and study possible associations between training regimen and locomotion asymmetry. This study is a pilot study. One hypothesis is that horses used for dressage, jumping or allround purposes are trained for the same number of sessions per week, but the number of minutes in different gaits could differ between disciplines. Another hypothesis is that allround horses may be more symmetric since they probably get the most varied training. Variation in training has been found to be a protective factor for lameness (Murray *et al*., 2010).

Background

Different training strategies

Eisersiö *et al*. (2015) made video recordings of eight riders riding three to them familiar horses each. Riders practiced different disciplines but were asked to ride a, for them, normal flatwork/dressage session. One session per horse were registered (n=24) and analyzed in detail. A mean training session lasted for 31 minutes and included 38% walk (~12 minutes), 39% trot

(~12 minutes) and 17% canter (~5 minutes). Walters *et al*. (2008) made a survey where they contacted the riders to all UK-registered dressage horses. Data were used from 2554 respondents. Riders answered questions about how they, (retrospectively) allocated their training based on their perception. Their mean sessions lasted for 36 minutes, including 21% walk (~8 minutes), 45% trot (~16 minutes) and 32% canter (~12 minutes). Lönnell *et al*. (2014) made a study on 263 European warmbloods used for show jumping, trained by 31 riders for 6 months. Each day the riders estimated the duration and components of their training. Their mean training session lasted for 31 minutes (min: 19 minutes, max: 42 minutes).

The number of training days per week and the variation in training type as factors of total number of trainings are also of interest. According to the riders in the study by Walters *et al*. (2008), dressage horses were dressage trained three to four times a week (~3.5 days per week). Each week 95% of the horses had some non-dressage exercise, hacking the most common, but lunging and jumping could also be alternatives. Non-elite horses were significantly more likely to receive this non-dressage training than the elite horses. In the study by Lönnell *et al*. (2014) the show jumpers were trained 4.7 ± 0.7 (4-6.2) times a week where 19% of these days were used for hacking (~1 day per week). The remaining training days could be either flatwork, jumping, competing, lunging etc.

Training and its effect on health

It has earlier been indicated that anatomical location and type of injury are affected by which discipline the horses perform. The level they trained/competed has also been shown to affect their locomotor? health. This suggests that type and site of an injury sometimes could reflect type and level of performance (Murray *et al*., 2006). There have been indications that dressage horses have a higher risk of suspensory ligament injuries than horses with an allround purpose (Murray *et al*., 2006). It has also been suggested that horses that moves extravagantly may have an increased risk of injury of these ligaments, especially their front limbs, if they aren't trained and strong enough for their tasks (Murray *et al.,* 2010). In horses used for show jumping there have been indications that injuries more often occur in the front limb superficial digital flexor tendon and the front limb distal deep digital flexor tendon (Murray *et al*., 2006).

In the UK study on dressage horses (n=2554) (Walter *et al*., 2008; Murray *et al*., 2010), 24% (n=605) had been recognized as lame at least once the last two years. Out of these, front limb lameness was most common with 43% (n=260) of the lameness episodes. Hind limb lameness occurred in 23% (n=141) of the lameness episodes. Various variables seemed to affect health, where a high number of training sessions per week were associated with a higher likelihood of lameness. Jumping and spending a large proportion of training time in working paces were examples of variables that were suggested as protective (Murray *et al*., 2010). In the study on show jumpers in different European countries (Lönnell *et al*., 2014) it could be seen that the intensity of training affected the number of days lost to training (days where they couldn't train due to health problems). The intensity interacted with competition class where horses jumping over 120 cm had a higher workload than the ones competing under this level. Horses with a higher workload also had more days lost to training (Lönnell *et al*., 2014).

It has been shown that Swedish warmbloods that had been placed in more than one discipline before the age of 7 had the longest competition career. Also, older horses with results from more than one discipline stayed in competition longer than the ones only competing dressage or show jumping (Braam *et al*., 2011). This could indicate that variation in training is positive for orthopedic health.

Sensors as a tool for training registrations

To get a good picture of how horses generally are trained there is a need of daily data on many participants with complete, repeated, and correct registrations of training sessions. As a tool for this, accelerometric sensors may be a good alternative. If riders can easily register their training sessions without help from other persons, it will be a way to get many and objective recordings. Inertial measurement units (IMUs) are microelectromechanic systems that combine gyroscopes and accelerometers to measure angular rotation and acceleration. A magnetometer can also be included to improve accuracy. IMUs are widely used today as controllers of motion-sensitive applications for smartphones. They are also used in human medicine and as a tool in different sports (Jost *et al*., 2017). IMUs are used in equine research and in work-up for lameness, for example they have been used to measure vertical pelvic movement as an indication of hind limb lameness (Pfau *et al*., 2013).

One 3D-IMU used for training registration in horses is Equisense (Lille, France) (sample frequency 60Hz) with one accelerometer, one gyroscope and one magnetometer combined in a single unit. Some of its functions is to register overall time of a riding session and time in different gaits. The gait detection algorithm, which is based on a pattern recognition algorithm, utilizes the delay between acceleration and the gyroscope. The gait detection is validated by Equisense using data from >100 horses. During this validation horses were tested ridden, with one minute in each gait (walk, trot, and canter). They were also tested lunged, with one minute in each gait in both leads. It has been stated to work well within some limits; there are problems with western horses and small ponies like Shetland ponies. The system also has some problems with detecting piaffe and passage. Equisense connects to a smartphone application via Bluetooth, which the riders use to connect to the motion and record their sessions. Collected data are used to calculate other parameters such as lead balance (time in each lead), number of transitions, number of jumps and elevation. It also includes a value on locomotion asymmetry in trot (Saute[1]). The latter is not validated against other more established methods of measuring asymmetry in trot and needs further evaluation.

Sensors for locomotion asymmetry measurements

Sensor systems can be used for objective recording of locomotion asymmetry. Registrations are preferably made from a well-used and validated system. Lameness Locator (Columbia, Missouri, US) is one such system. The function of Lameness Locator requires basic understanding of a horse's locomotion. A stride is defined as a full cycle of limb motion. For each limb this cycle has two different phases; the stance phase where the hoof has contact to the surface, the swing phase where the hoof doesn't have contact with the surface, and the suspension phase where in trot and canter, no hoof has contact to the ground (Barrey, 1999).

Trot is a two-beat gait where each beat corresponds to the movement of two diagonal pairs of limbs. In trot, a horse raises and lowers its head and pelvis twice during one stride, doing so in a relatively simultaneous manner. In principle, the head is at its lowest position around

[1] Camille Saute (camille@equisense.fr), Equisense, 2018-05-07

midstance phase of each front limb, and the pelvis at its lowest position during stance phase of each hind limb (Buchner *et al*., 1996). The vertical movements of the body should be the same for the two parts of the gait cycle i.e. head and pelvis should be lowered simultaneously when the two diagonal pairs of limbs are moving. In a lame horse these movements change, and an asymmetry develops, when the two parts of the stride are compared (Sørensen *et al*., 2012). In a front limb lameness, the horse gets the classic "head nod", where the head lowers more during the stance phase of the healthy limb and lowers less during the stance phase of the lame limb (Pfau *et al*., 2016). In a hind limb impact lameness, the mechanism is similar where the pelvis lowers more during stance phase of the healthy limb and less during stance phase of the lame limb. Tuber sacrale and tuber coxae are anatomical locations that can be of interest to study movement asymmetry (Kramer *et al*., 2004). With knowledge of how the horse change its movements in these parts during a lameness it is possible to detect even small asymmetries by measuring the vertical movement of head and pelvis (Buchner *et al*., 1996).

The Lameness Locator is a 3-inertial sensor system that consists of two accelerometers, one placed on the horse's head and one on the sacrum. A gyroscopic sensor is also used on the right front limb; this informs the system about which diagonal pair of limbs that is on the ground. With data from the sensor on the head, asymmetry relative estimates are produced on how many less/more millimeters the head moves vertically, up or down, during one diagonal of the gait cycle, compared to the other diagonal, and this is used to evaluate front limb asymmetry. The calculations produced one minimum difference value (HDmin), which represents the difference in head minimum positions between right and left portions of the stride, and one maximum difference value (HDmax), which represents the difference in head maximum positions between right and left portions of the stride. In the same way values are given about differences in vertical excursion of the pelvis (PDmin and PDmax), and these are used to measure hind limb asymmetry. The information about how head and pelvis move vertically will indicate if the horse shows a possible front or hind limb asymmetry and suggest which limb that has induced it. HDmin and HDmax <-6.0 or >6.0 mm are considered by the manufacturer to indicate significant front limb asymmetry, given that the value is higher than the standard deviation (SD). PDmin and PDmax <-3.0 or >3.0 mm are considered to indicate significant hind limb asymmetry if the value is higher than SD. A totally symmetric horse will have values at zero (Keegan *et al*., 2011).

Materials and Methods

The study was performed in three different stables in the middle of Sweden (Uppsala, Knivsta and Kolbäck). Stables known to the author was chosen and all riders in these stables with horses in training were asked to join. A total of 29 riders with 34 horses were initially enrolled in the study, after some dropouts 24 riders with 29 horses completed all parts of the study. All horse owners signed a form at startup of the study, with their permission to use their horses for measurement during the study and to use the data for further studies (Appendix 1). The study lasted for eight weeks during spring/summer 2017.

Riders, horses and management

Horses were privately owned and used for either dressage (n=15), show jumping (n=5) or allround purposes (n=9), including eventing. In stable A there were 9 horses used for dressage and 2 for allround, in stable B there were 3 horses used for dressage, 2 for jumping and 2 for allround, and in stable C there were 3 horses used for dressage, 3 for jumping and 4 used for allround purpose. Both riders and horses were in different levels of education, but all riders had the aim to compete. Riders where between 15 and 64 years old, horses between 4 and 17 years old. The withers height of the horses ranged from 150-190 cm. Most riders had one horse, but a few had more (rider A; 6 horses, rider B; 2 horses). All horses were stabled in boxes during the night and out in paddocks of different sizes for 3-8 hours per day. Most of the horses were kept one by one in the paddocks but some had company of another horse. Some of the horses went out on pasture during summer and some remained in their usual paddock. The three stables had riding facilities with at least one indoor and one outdoor arena. Horses were fed roughage analyzed for nutrient content but not all had a calculated ration. All were fed concentrates in some form, between 0,5-4 kg, most of them not more than 1 kg/day.

Training and locomotion symmetry registration

Riders were equipped with an Equisense single sensor that was attached to the girth of their horse's saddle and could connect to the Equisense application that was downloaded to each rider's smartphone. When enrolled, riders were asked to use the sensor and application every training session for a duration of eight weeks. In the application the riders could register their session and choose which kind of session they had performed (dressage, jumping, hacking etc.). Riders were also asked to make complementing notes on a paper each week. These notes included if they had been training or not, and what kind of sessions they had performed each specific day. The riders should also note if any problems with the training registration had occurred. These notes on paper could later be used as complementing data if there had been problems with the registration in the application.

During the study period horses were also measured with the Lameness Locator once a week to collect longitudinal asymmetry data on each horse. Horses were assessed at trot by hand in a straight line, both on hard and soft footing. In most cases the riders assisted during the registrations. They held their horse when the equipment was placed on the horse's head, pelvis, and right front limb, and they ran with their horse during the registration. Riders did not get to see results from these measurements during the study period as this could influence their training and thoughts about their horse. Some few exceptions were made when a horse was obviously lame and had changed a lot in asymmetry since the last time. In the same day as the locomotion asymmetry registration took place, riders also answered questions about how their last week of training had been. Focus was on the question; "have your horse felt good/as usual during the last week of training, yes or no?" This was asked for elucidation of whether variation in asymmetry had affected the riders' impression.

After the eight weeks had passed all riders received diagrams of how their horses had varied in locomotion asymmetry from the measurements with Lameness Locator. To present one value for fore and hind limb asymmetry, results were presented as vector sums, where a vector sum of zero was a totally symmetric movement (calculations see below). The riders were offered the opportunity to continue to use Equisense as a tool in their training and for possible further studies.

Statistical methods and calculations

Training data from Equisense were downloaded from their platform https://research.equiesenseapi.com. Values for the total duration of a mean 'standard' session per horse and week, and the distribution between gaits during the standard session, were calculated. These sessions were compared between weeks, stables and disciplines.

SAS 9.4 was used for all statistical analyses. A mixed model including the repeated effect of horse and the fixed effects of week, stable and discipline were used to analyze possible differences. The distributions of the dependent variables were regarded to be normal enough to be used in this model. Differences between two different session types; arena sessions and hacking sessions (including hacking), were also analyzed regarding the total time per session and distribution between gaits. The same model was used but with session type as a fixed effect instead of discipline.

A "normal training week" (weeks when horses were assessed to be healthy by their riders and in normal training) including the total number of training days and number of days trained in arena and out hacking were also analyzed with a mixed model including repeated effect of horse and fixed effects of week, stable and discipline. Missing recordings could in this case be replaced with notes from the rider as mentioned above.

From the lameness locator output, absolute vector sums (VS) were calculated from HDmin, HDmax, PDmin and PDmax (√(HDmin^2 + HDmax^2), √(PDmin^2 + PDmax^2)). In this way two positive values that represent asymmetry could be used, one that represent front limb asymmetry (from HDmin and HDmax) and one that represented hind limb asymmetry (from PDmin and PDmax). Instead of using the guidelines from Keegan *et al*. (2011) for what was considered as a significant asymmetry, study-specific threshold values were calculated based on a 95% prediction interval from the data of the study population, where measurements above these values were considered to be above normal (see calculations below). The following VS thresholds for each category were used:

95% prediction interval calculation for thresholds (mean + SD*1,96):
front, hard footing: 9,30 + 6,49 * 1,96 = 22,04
front, soft footing: 8,30 + 5,47 * 1,96 = 19,02
hind, hard footing: 4,81 + 2,85 * 1,96 = 10,4
hind, soft footing: 4,28 + 2,72 * 1,96 = 9,61

Possible differences in vector sums between weeks, stables and disciplines were analyzed using a mixed model including the repeated effect of horse and fixed effects of week, stable and discipline. Least square means on the vector sums were calculated for each discipline on front and hind limb asymmetry. After this, the total proportion of registrations (both front and hind) where the VS were greater than the threshold described above, was compared between disciplines with a chi^2 test. Only measurements from horses that were considered sound by their owner were used in this test.
Possible correlations between the number of trot and canter during sessions and vector sums were analyzed calculating Pearson's correlation coefficients.

To study if VS at the weekly measurement affected the rider's impression of the horse during training, the rider impression of the horse's performance (as normal, yes/no) was included as a fixed effect in a mixed model including a repeated effect of horse and fixed effects of week and stable analyzing VSs as the dependent variable.

Results

Training

A normal training week (n=139 weeks) included a mean (±std) of 5.0±1.4 training sessions, with 4.0±1.4 days training in an arena and 1.0±1.0 days out hacking with no difference between disciplines (P>0.05). There was a general difference in number of days with training between weeks (P<0.05), where riders trained less during week 6 than all other weeks (P<0.05) (figure 1). There was also a difference between stables (P<0.05). The number of days hacking outside differed between weeks (figure 2) (P<0.0001) where riders where hacking outside fewer days in week 6 and 7 than during week 2, 3, 4, 5 and 8 (P<0.05). This also differed between stables (P<0.01), but not between disciplines. How many training sessions performed in the arena differed only between stables (P=<0.0001) and not between weeks (figure 3).

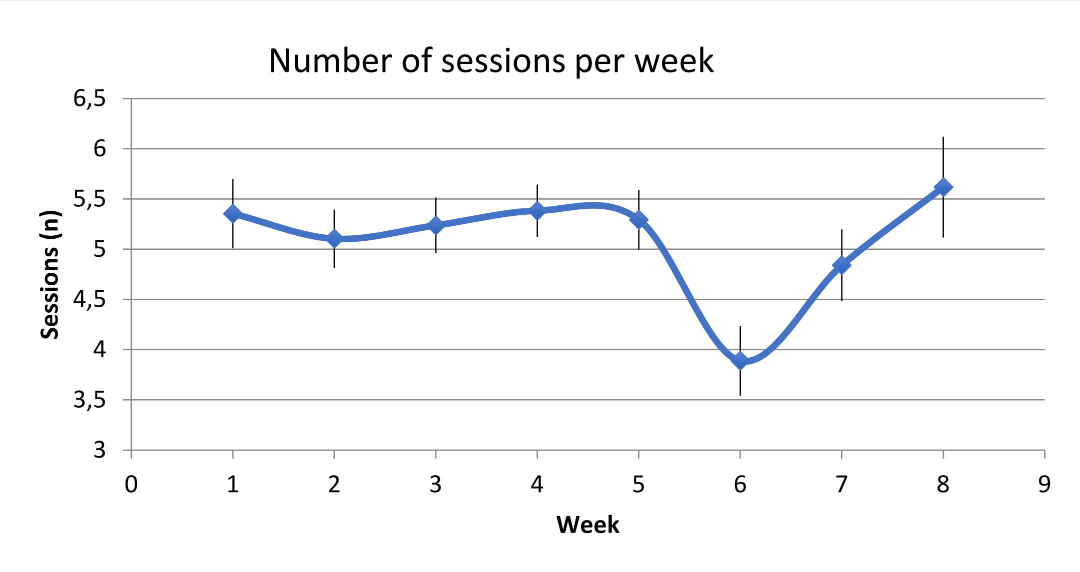

Figure 1. Least Square (LS) means (±SE) of the total number of sessions per week.

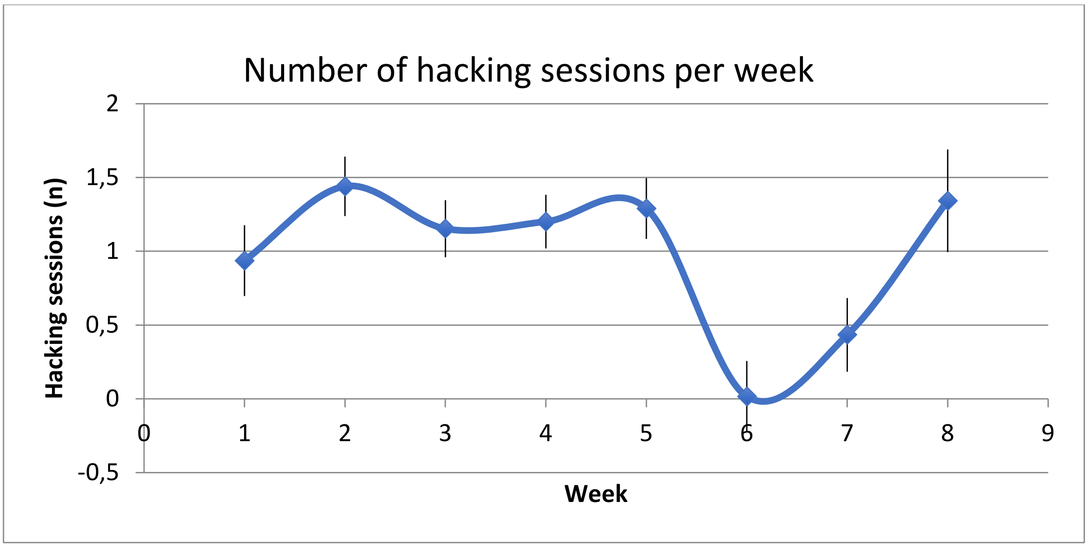

Figure 2. LS means (±SE) of the total number of hacking sessions per week.

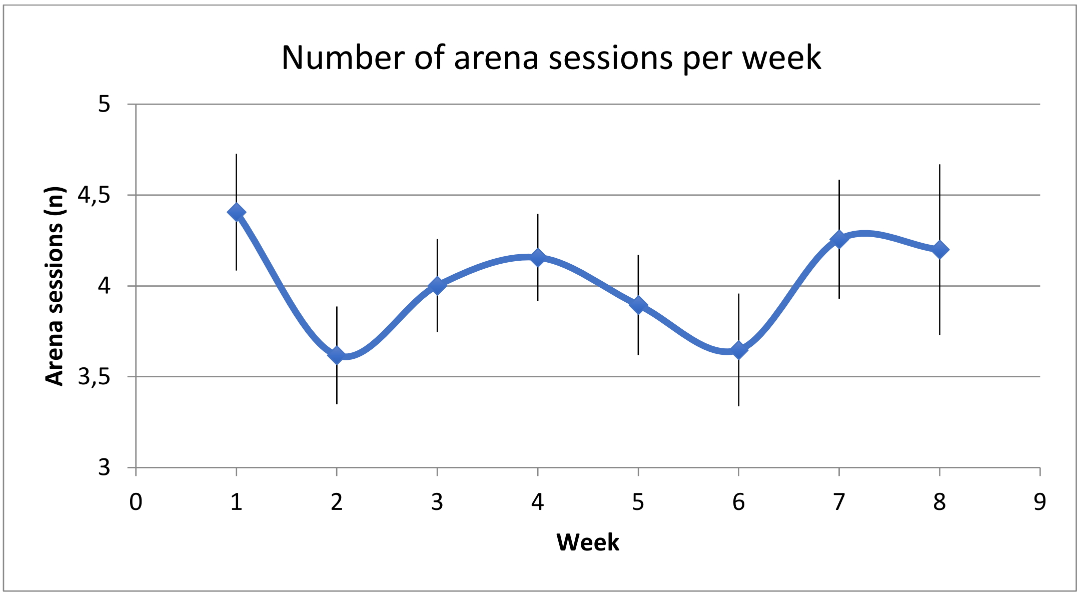

Figure 3. LS means (±SE) of the total number of arena sessions per week.

Equisense registrations were available for a total of 663 sessions. A mean training session lasted for 42±9 minutes including 25±8 minutes of walk (~58% of the duration), 11±4 minutes of trot (~26%) and 7±3 minutes of canter (~16%). There was no difference between disciplines for the total length of a session or the time spent at walk, but there was a general effect for the duration of trot ($P<0.05$) and canter ($P<0.01$) performed within a session (Figure 4). Horses used for dressage were trotted more (12±0.6 minutes) than the allround horses (9±0.7 minutes, $P<0.01$), and cantered less (5±0.5 minutes) than both the show jumping horses (8±0.6 minutes, $P<0.05$) and the allround horses (8±0.9 minutes, $P<0.01$).The proportions of different gaits performed in a session within different disciplines are showed in figure 5. The total length of a session differed amongst stables ($P<0.01$), and so did also the number of minutes in canter ($P<0.01$).

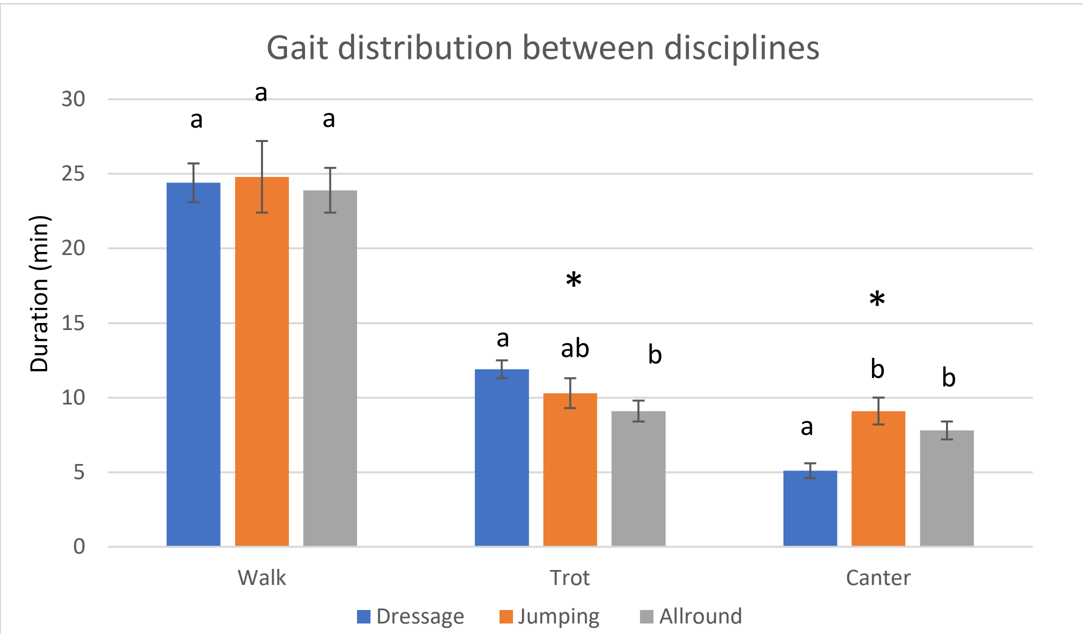

Figure 4. Number of minutes per session in different gaits for horses used for either dressage, jumping or allround purposes. Stars indicate a general effect of discipline on number of minutes performed in the presented gait (P<0.05). Different letters (a and b) indicate a difference within gait between disciplines (P<0.05).

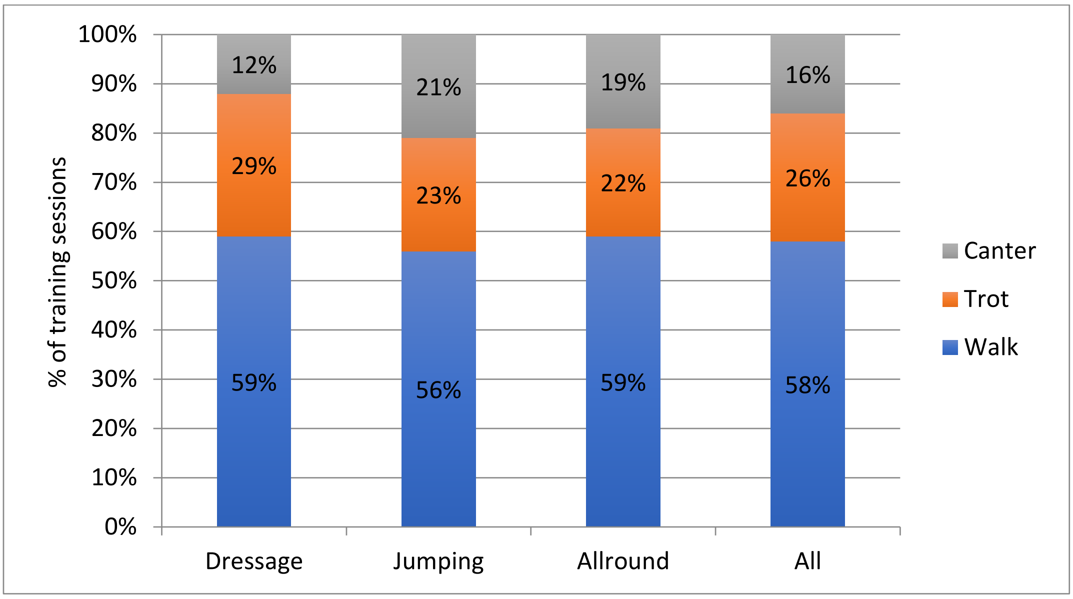

Figure 5. The proportion of different gaits performed during training sessions shown per discipline stated by the rider that the horse was mainly used for and in total for all horses.

Sessions with recording were divided into two different types, arena sessions (n=415) and hacking sessions (n=93). Session type did not affect the total length of a session but affected the gait distribution within session (P<0.01). In the arena the horses walked less (24±2 minutes) than during hacking (33±2 minutes, P<0.01), but they were trotted and cantered more in the arena (12±1 and 9±1 minutes) than during hacking (4±1 and 4±1 minutes, P<0.0001) (figure 6).

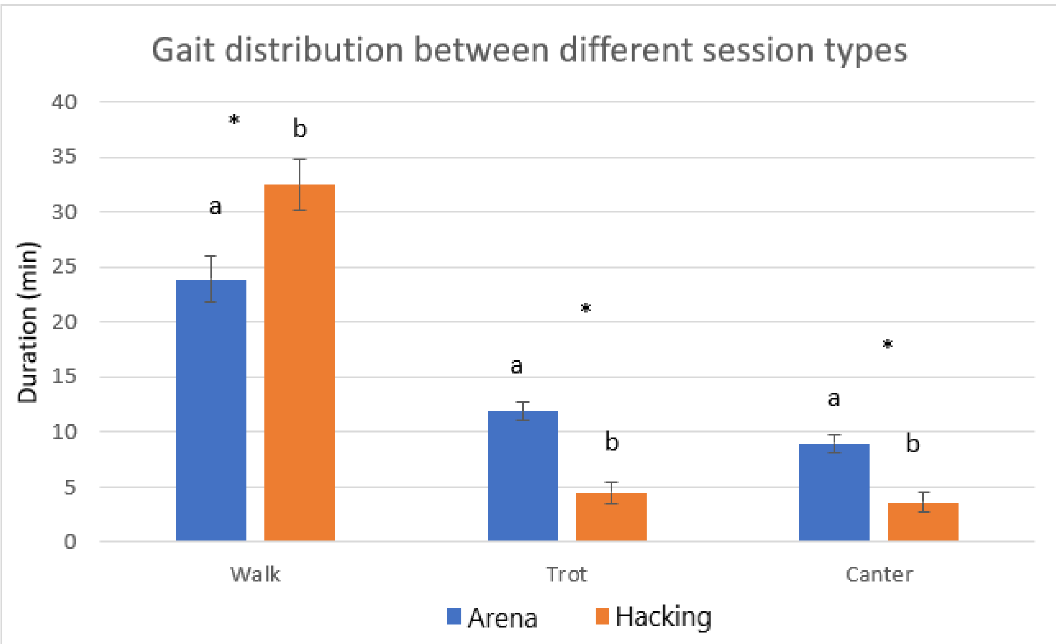

Figure 6. Number of minutes in different gaits per session in either arena or hacking sessions. The star indicates a general effect within gait between session types. Different letters (a and b) indicate a difference within gait between session types.

Locomotion asymmetry

From vector sums for front limb asymmetry there were 16 vector sums above the threshold on hard footing (figure 7), and nine above the threshold on soft footing (figure 8). From vector sums for hind limb asymmetry there were nine above the threshold on hard footing (figure 9), and eight above the threshold on soft footing (figure 10).

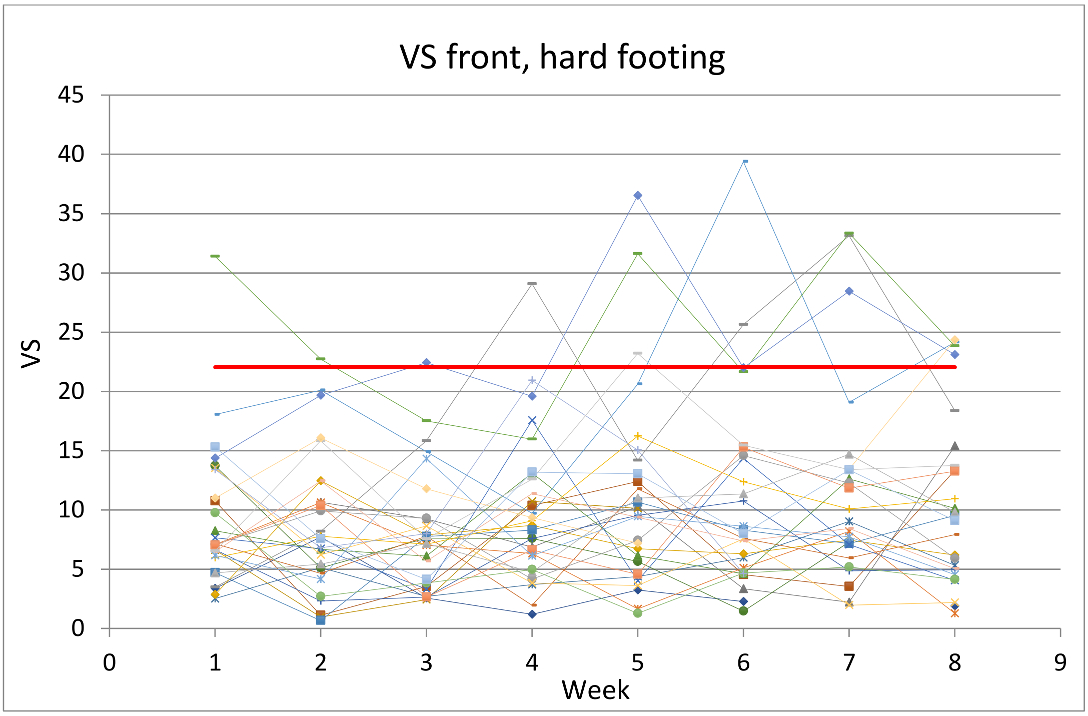

Figure 7. VS on front limb asymmetry, hard footing. 16 VS measurement points were above the threshold (red line) Values from each horse are connected.

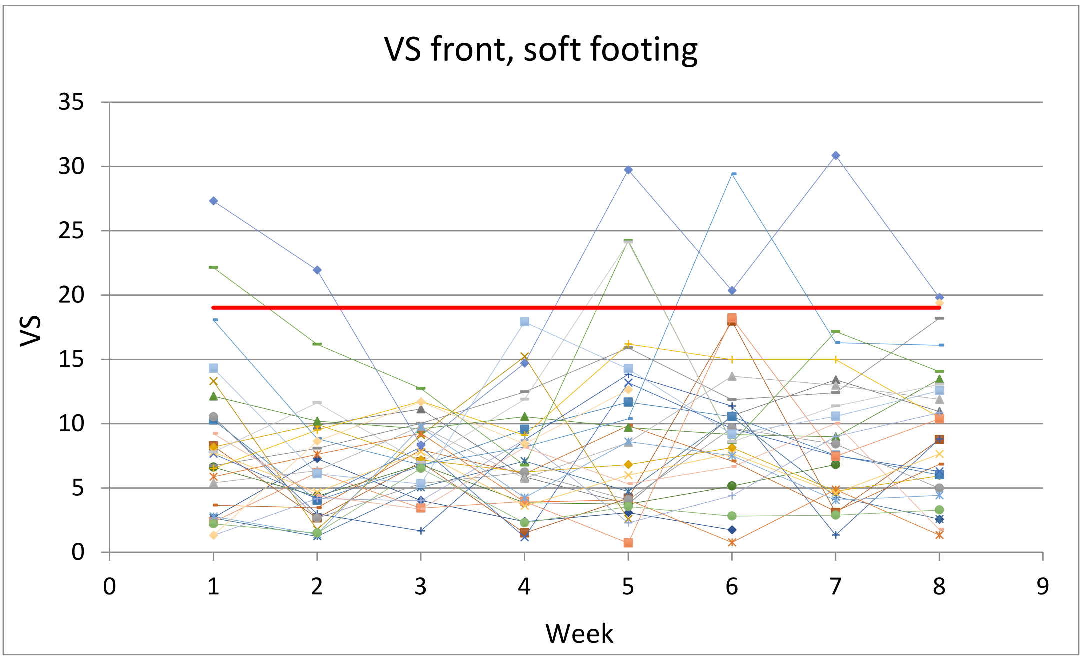

Figure 8. VS on front limb asymmetry, soft footing. Nine VS measurement points were above the threshold (red line). Values from each horse are connected.

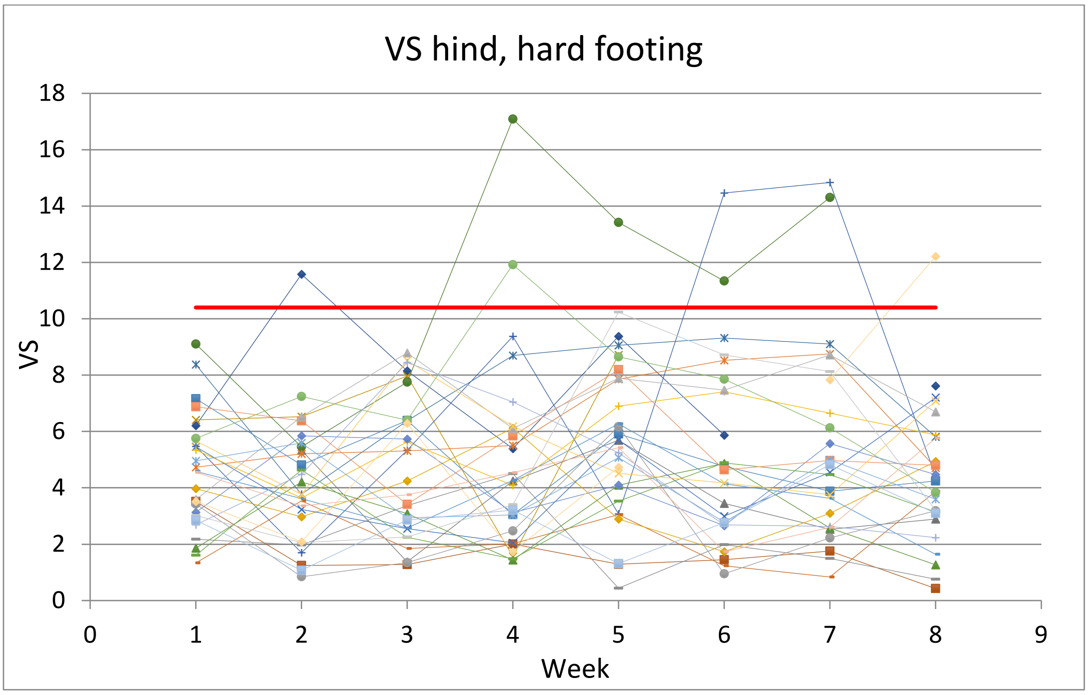

Figure 9. VS on hind limb asymmetry, hard footing. Nine VS measurement points were above the threshold (red line). Values from each horse are connected.

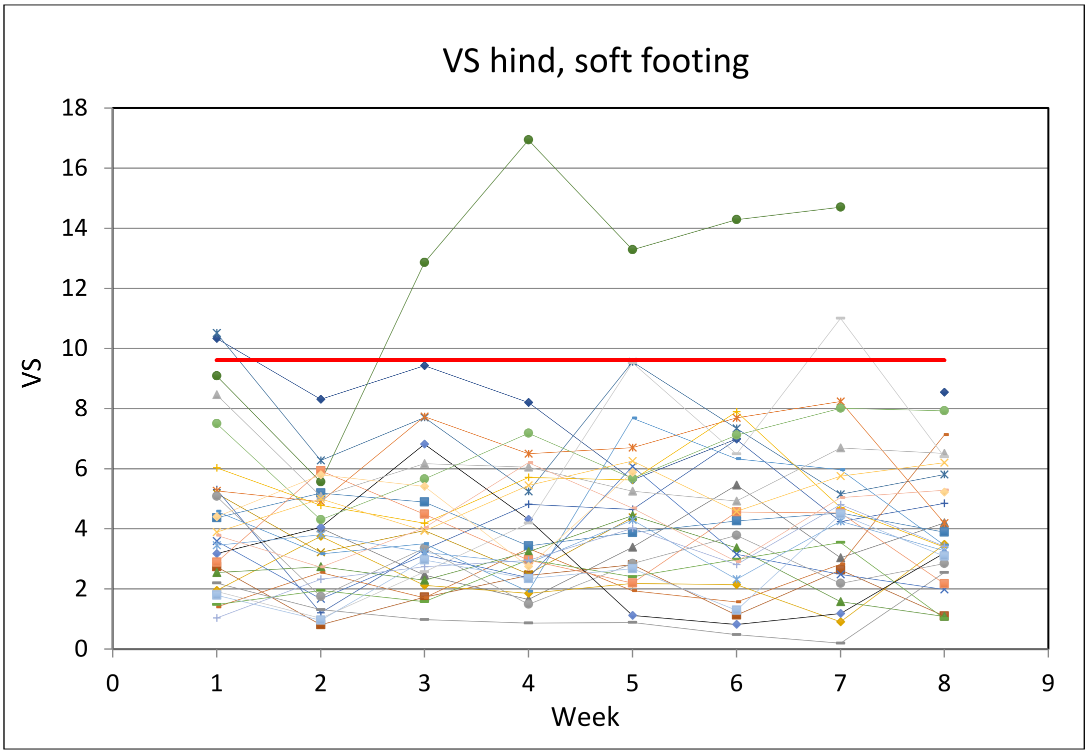

Figure 10. VS on hind limb asymmetry, soft footing. Eight VS measure points were above the threshold (red line). value. Values from each horse are connected.

Regarding the vector sum for front limb asymmetry, there was a general effect of stable (P<0.0001) and week (P<0.05). During week 1 the VS was lower than during week 6 (P<0.05) and during week 2, 3 and 4 the VS was lower than during week 5, 6 and 7 (P<0.05) (figure 10).

In hind limbs, there were a general difference between weeks (P<0.05) where VS was lower during week 2 than during week 3, 5 and 7 (P<0.05). During week 4, VS was lower than week 5 (P<0.05) and during week 7, VS was higher than week 8 (P<0.05) (figure 12).

The horses used for dressage showed a greater asymmetry on front limbs (10.45±0.68) than the horses used for allround purpose (8.34±0.78, P<0.05) (figure 13). There were no differences between any of the disciplines on hind limb asymmetry.

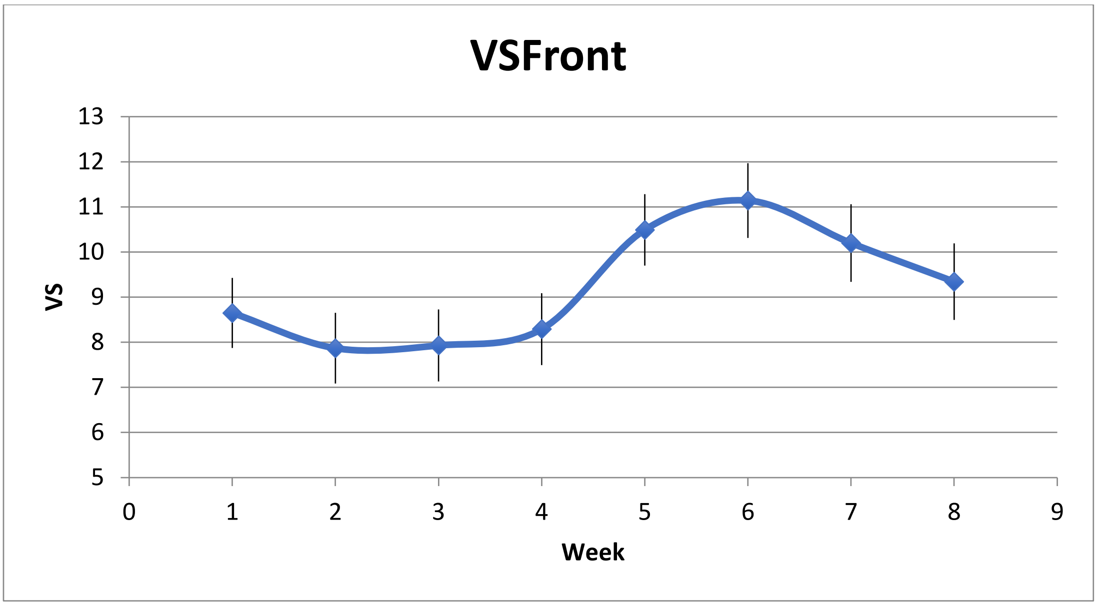

Figure 11. The variation between weeks on LS Means (±SE) of vector sums on front limb asymmetry.

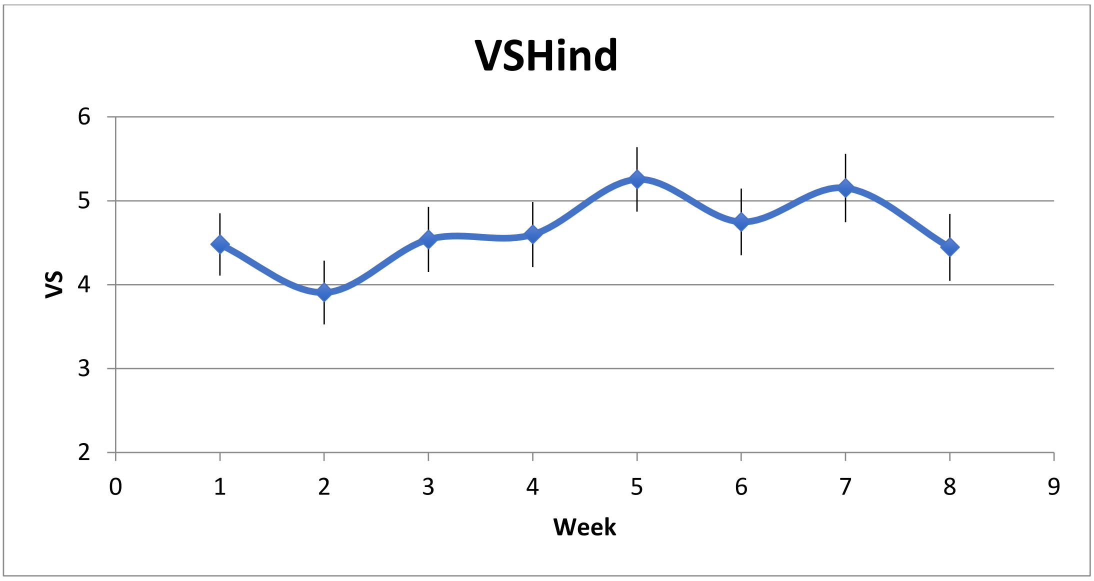

Figure 12. The variation between weeks on LS Means (±SE) of vector sums on hind limb asymmetry.

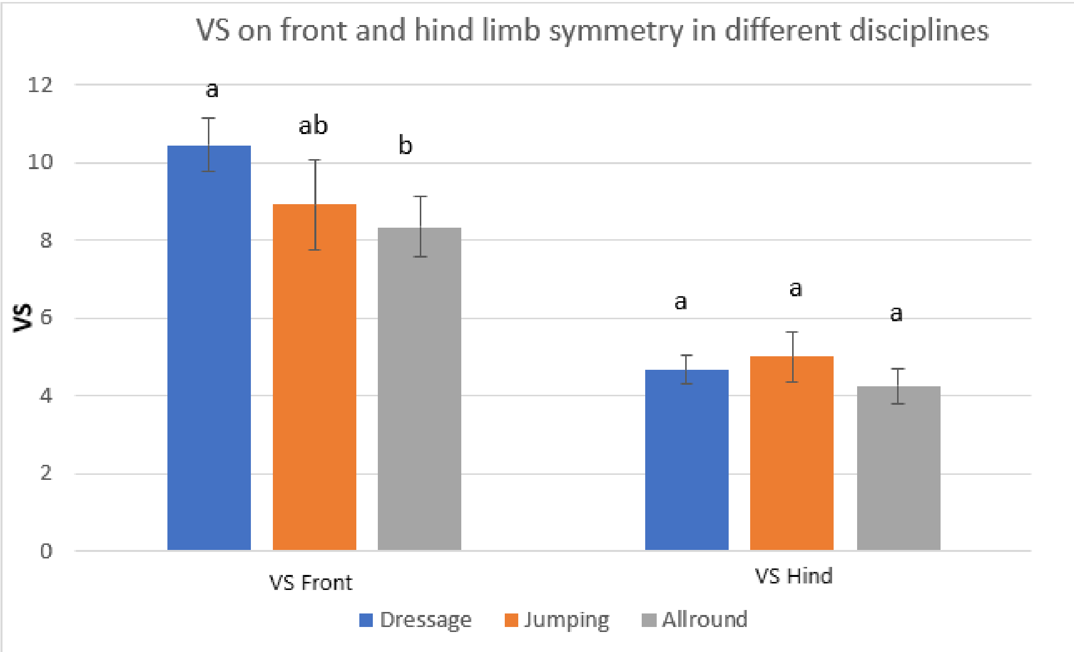

Figure 13. Differences between vector sums on front and hind limb asymmetry in different disciplines. For each asymmetry, letters (a and b) indicate a difference in VS between disciplines.

There was a weak positive correlation ($r=0.165$, $P<0.01$) between vector sums on front limb asymmetry and the number of minutes in trot per session, i.e., more trot per session was related to a higher vector sum. No other statistically significant correlations were found. There was no effect of increased locomotion asymmetry on the rider's impression of the horse.

Discussion

Eight weeks of training registrations

To increase understanding of training impact on injury development as well as on performance in riding horses, accurate registration of training is essential. This pilot study targeted such registrations and found that it was feasible to work with this in research. However, for accurate registrations, both a reliable (preferably independently validated) and user-friendly device as well as good rider compliance are crucial. Some riders had problems with the connection between the sensor and its application, 663 training sessions were used to analyze training data. If all riders rode 5 sessions a week the resulting number of sessions would have been 1160. This is clearly in discrepancy with the 663 sessions. Riders were asked to note if they had trained (and what type of session) if the recording had failed which facilitated the quantification of the number of sessions lost to recording problems.

A normal training week was based on weeks when horses were assessed to be healthy by their riders and in normal training. The number of training sessions taking place during such a normal training week is a useful comparison evaluating training regimens. If only one session or one week is measured it is easy to miss that the horses could be trained totally different during other sessions or other weeks. During week 6 horses were trained significantly less compared to the other weeks. They were also out hacking significantly less this week. If the study had been performed during only this week the results would have been different. This shows the importance of a longer period of registrations relative to this concern. However, the result in this study is in line with previous studies where the dressage horses were dressage trained 3-4 times a week and most of them had also one day with alternative training, hacking the most common (Walters *et al*. 2008). Show jumpers have been reported to train 4.7± 0.7 days per week where ~1 day per week were used for hacking (Lönnell *et al*. 2014).

Gait distribution during a training session

The distribution between gaits during a session varied a bit from earlier studies; more trot than canter seems to be standard but the proportion of walk in this study (58%) was much higher than what found by others (38% and 21%, Eisersiö *et al*., 2015 and Walters *et al*., 2008). Eisersiö *et al*. (2015) discussed that the total time of a training session from their study could be a bit short (31 minutes) and that this could depend on that their riders rode three horses in a row, were professional riders (with limited time for each horse) or perhaps that the riders were affected about being video recorded. Their horses trotted for ~12 minutes and cantered for ~5 minutes, which is similar to horses in this study. Perhaps these sessions seemed short due to the small proportion of walk (~12 minutes). Their recording started when the rider had mounted the horse and ended at dismounting. In this study, recordings were instructed to start when leaving the stable and end when coming back to the stable. Due to some problems with the application this could also have varied during the study why the number of minutes in walk should be regarded with some caution. It is possible that the horses in the study by Eisersiö *et al*. (2015) had been walked by hand or walked in a walker before the recordings started since this is quite normal amongst professional riders to save time. In the UK study (Walters *et al*., 2008) horses walked even shorter; ~8 minutes. Perhaps there were similar circumstances there in how riders measured their sessions and some walk by hand etc. was excluded. For future studies of training, clear directions according how much walk that should be included would be beneficial. An overall opinion during this study with Equisense was that riders were surprised of the short time spent in trot and canter. This is one factor to why it is so important to register training objectively and not by, for example, interviews with riders.

There were some between-discipline differences in how a training session was performed regarding gait distribution. This could maybe be explained by the many exercises in trot in a dressage program and the lack of trot in a show jumping test. These differences need to be tested further. If the findings reflect a general difference between the disciplines, it could be one cause that leads to different effects on orthopedic health. Of course, it also needs to be taken in consideration that there are many other factors than the distribution between gaits that contributes to how a riding session is performed and how it affects orthopedic health. In this study we measured the total time in each gait, but it would be interesting to look further into transitions, how many reprises of gaits that are performed and the durations of each gait reprise for example. Eisersiö *et al*. (2015) also suggested that heart rate of horse and rider should be included to explain workload.

Differences in locomotion asymmetry between disciplines

The VS for front limbs were greater in horses used for dressage than in horses used for an allround purpose. It could be speculated that dressage horses should move more symmetric since dressage riders aim for a straight horse with a clear two-beat movement in trot. However, it has also been reported earlier that training variation is important for health and performance

(Braam *et al*., 2011). The allround horses in this study probably had the most varied training since many of them competed both in dressage and jumping, and some also in eventing. It could also be seen that there was a weak positive correlation between more trot and a greater locomotion asymmetry, and as earlier discussed the dressage horses trotted more than the allround horses. Many other factors could also have influenced these results such as rider, footing, and other management routines, which is important to have in mind. More recordings are needed to determine if these differences are present even in a larger population. Increased workload has previously been linked to a higher likelihood of lameness. (Murray *et al*., 2010; Lönnell *et al*., 2014), but it was not possible in this study to see whether horses from different disciplines trained with different intensity, at least there were no differences in the number of sessions per week or the total length of a session.

Variation over time in locomotion asymmetry

It would be intriguing to look deeper into the variations in locomotion asymmetry between weeks, as it appeared to exhibit significant variability, particularly in certain horses. These fluctuations need to be quantified to determine the extent of normal variation and identify magnitudes that could potentially indicate early signs of lameness. Additionally, factors such as discipline and breed may influence what is considered a normal range of variation (Sepulveda Caviedes et al., 2018).

In a study involving thoroughbreds undergoing race training, repeated gait analyses were conducted to examine such variations. The findings revealed considerable variability in asymmetry, both within days and across weeks. Notably, there was more substantial variation in front limb asymmetry (50% within 5-7 mm; 90% within 18-19 mm) compared to hind limb asymmetry (50% within 4-5 mm; 90% within 12-13 mm) (Sepulveda Caviedes et al., 2018). The horses were not examined by a veterinarian but were deemed sound by their trainers, similar to the circumstances in this study, although with different training regimens. A variation ranging from 4 to 19 mm represents a range in vector sums (VS) from approximately 6 to 27. This range appears to align with the weekly variations observed in some of the horses in this study, although most exhibited smaller variations. This discrepancy might be attributed to the differing training methods, supporting the notion that discipline can influence the normal variation in locomotion asymmetry.

Interestingly, the riders' impressions of the horses remained consistent even when there were variations in asymmetry. This observation may suggest that riders face challenges in detecting such variations or, alternatively, that many of the observed variations are within the realm of normalcy and do not adversely impact the horse's performance during training. The study by Sepulveda Caviedes et al. (2018) supports the idea that these variations might indeed be normal. It would be valuable to explore further correlations between training and locomotion asymmetry to ascertain whether this "normal" variation can be influenced by variations in training. Another study by Ringmark et al. (2016) indicated that the introduction of speed- and uphill interval training during spring in Standardbred racehorses led to increased locomotion asymmetry, interpreted as an effect of the training regimen.

Threshold values based on study population

Different threshold values than the ones earlier made by Keegan *et al*. (2011) was used in the present study. In an earlier study, over 72% of warmblood riding horses that were owner sound were above the threshold values employed for the Lameness Locator (Rhodin *et al*., 2017). Therefore, it was interesting to test other threshold values based of what was normal in this population. Since all riders received diagrams of how their horses had varied in asymmetry during the weeks and when (if) they had VS above threshold, it was decided to use these higher threshold values as these probably were more relevant for the current population. In another study on thoroughbreds in race training, locomotion asymmetry values were compared with veterinary opinions. The veterinarians detected lameness on horses with asymmetry measurements on front limbs >14.5 mm and on hind limbs >7.5 mm (Pfau *et al*., 2018). This also indicates that the earlier made threshold values could be a bit low.

Conclusion

Even in this small study, there was variation in training regimens among horse groups used for different disciplines. This indicates that results from larger groups of horses could provide more relevant information on correlation between training session composition and development of asymmetry. However, for accurate registrations, a reliable and user-friendly device as well as a good rider compliance are crucial. In this horse population, the number of minutes spent in trot and canter was associated with the discipline the horse was mainly used for. Horses used for allround purposes showed less asymmetric movement at trot by hand compared to horses used for dressage. The weekly variation in locomotion asymmetry is interesting and need further investigations to elucidate how large variation that is normal in different disciplines, and different horses, and further on how variation in training affects the variation in locomotion asymmetry.

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Appendix 1

DJURÄGARSAMTYCKE:
INFORMATION INFÖR DELTAGANDE I STUDIEN
”Samband mellan träning, underlag, skötsel och rörelsesymmetri”

SYFTE:
Syftet med studien är att kvantifiera den träning som används vid träning av ridhästar och att undersöka om det går att finna samband mellan träning, underlagsanvändning, övriga faktorer i hästarnas skötsel/närmiljö och förändringar i hästarnas rörelsesymmetri.

UTFÖRANDE:
Studien innehåller flera delar och här nedan kan du ge ditt samtycke till den/de delar som du och din häst kan delta i.

1) Registreringen av träningsdata görs med hjälp av en sensor, Equisense, som är kopplad till en mobilapp. Sensorn fästs med kardborre runt sadelgjorden och data från sensorn lagras på en extern server. Sensorn bör om möjligt användas vid alla träningspass. Kopplat till sensorn finns en träningsdagbok som bör fyllas i på daglig basis.
2) Registrering av rörelsesymmetri genomförs med hjälp av systemet Lameness Locator där 3-4 sensorer (storlek som en liten tändsticksask) fästs på hästen med hjälp av tejp, benskydd, grimma med luva samt pappersklämmor som fästs i pälsen. Sensorerna är små och lätta och förväntas ge minimal påverkan på hästen. Registreringen av rörelser sker i trav vid hand på rakt spår samt vid longering i trav på både hårt och mjukt underlag.
3) Basdata häst: Hästen kommer att palperas för bedömning av kroppshull och mätas med måttband och mätsticka för registrering av mankhöjd, bröstomfång och nackomfång.

Inga speciella komplikationer förväntas vid ovanstående behandlingar. Djurägaren kommer ombes svara på ett antal frågor om hästen rörande historik och skötselrutiner. All insamlad data kan komma att användas i forskningssyfte och presenteras anonymt. Studien finansieras av Svenska Djurskyddsföreningen.

SAMTYCKE:
Jag ger mitt samtycke till att min häst används till följande (kryssa för i rutan):

☐ Registrering av träningsdata med hjälp av Equisense

☐ Registrering av rörelsedata med hjälp av Lameness Locator

☐ Registrering av basdata häst enl. ovan.

☐ Om jag inte har möjlighet att närvara vid någon av mätningarna med Lameness Locator och basdata häst kan annan av mig utsedd person hantera min häst under mätningarna (ej första mätningen).

Härmed intygas att jag frivilligt lånar ut den/de hästar jag äger/företräder/ansvarar för för att delta i den ovan beskrivna studien. Jag har muntligen informerats om studien och tagit del av och förstått ovanstående skriftliga information. Jag är medveten om att deltagande i studien är frivilligt och att jag när som helst kan avbryta deltagandet. Jag kan inte kräva ersättning av SLU om hästen/hästarna blir sjuk/halt/skadad under eller efter projektperioden.

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Hästnamn

…....................................
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Ort, datum   Underskrift av ägare/ombud

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