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Final report

Lameness or laterality: when does asymmetry matter?

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Part 1: Detailed summary

Short description of objective, method, main results, importance for the horse sector, and recommendations.

Lateralitet, höger- och vänsterhänthet, är ett välkänt fenomen hos människor och djur. Ortopediska sjukdomar hos hästar är vanliga och visas ofta som en hälta. Den subjektiva bedömningen av hältor är svår och därför har metoder att mäta hältor (rörelseasymmetrier) utvecklats. I en studie av ridhästar i träning hade 73% ett oregelbundet rörelsemönster vilket väckte frågan om det är orsakat av smärta eller en naturlig lateralitet? Vid rekryteringen av unga rid- och travhästar till en långtidsstudie visade det sig att 73 % respektive 88% av hästarna rörde sig asymmetriskt vid studiens start innan de hade påbörjat sin träning. Då det förekommer utvecklingsrubbningar som ger upphov till hälta, vet vi inte om asymmetrierna kan vara orsakade av smärta. Vi saknar därför en mycket viktig pusselbit, kan ett föl födas med en naturlig rörelseasymmetri och finns det en koppling till fölets lateralitet? Därför ville vi studera förekomsten av rörelseasymmetrier och lateralitet hos föl och kopplingen dem emellan. Genom att initiera datainsamling om hästarnas lateralitet i långtidsstudierna av de unga hästarna samt i en grupp av högpresterande ridhästar kunde vi samla in stora mängder data. De preliminära resultaten visar att rörelseasymmetrier även är väldigt vanliga hos föl medan motorlateralitet verkar vara mer ovanligt både hos föl och unga ridhästar. Hos högpresterand ridhästar fanns inget samband mellan rörelseasymmetrierna och ryttarens uppfattning om hästens sidighet. Vi har inte kunnat påvisa att det finns en tydlig motor lateralitet hos hästar som orsak till rörelseasymmetrier. Därför vet vi ännu inte om det finns andra orsaker än smärta till rörelseasymmetrier. Därför är det oerhört viktigt att man vid hältutredningar använder diagnostiska bedövningar för att säkerställa att en häst med rörelseasymmetrier har ont.

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Part 2: Main report

Introduction

Background and objective.

Many young riding horses show motion asymmetries even before training begins. Motion asymmetry is a well-known sign of lameness, used in modern lameness detectors that relies on measurements of vertical movement asymmetry. However, we don't know if asymmetries always reflect pain caused by orthopaedic pathology, or if some horses simply prefer to use one side of the body or brain more than the other. If both these reasons for movement asymmetries exist, we need to redefine lameness in terms of asymmetry of the movement, revisit the use of movement symmetry as a proxy for orthopaedic pain and pathology, as well as reveal methods to distinguish between the two conditions [1].

The term laterality refers to the preferred use of one side of the body over the other. Motor laterality is the preference for using muscles of one side of the body, reflecting asymmetries in the brain as studied in animals [2–4]. The repeated practice and habit formation train the preferred side slightly more and thus stabilizes the laterality by muscular growth.

Motor laterality has been investigated and identified in many species, such as dogs [5], cats [6] and humans, 93% of whom prefer the right hand for fine motor skills [7]. There is strong evidence to support hereditary traits for motor laterality in both humans and animals, and breed differences in motor laterality have been reported in horses [3] and dogs [5]. Peculiarly, the clock-wise direction of hair whorls have also been associated to handedness in humans, and anecdotally, that same phenomenon has been associated to behavioral traits in horses. Furthermore, laterality is associated to sex, mares and bitches show a strong right-sided dominance [5,8]. In horses, motor laterality has been investigated by studying limb preference during grazing [3] or during initiation of movement and direction when avoiding an obstacle [9]. In a study of 24 foals, 46% developed a preference for stretching out one limb over the other during grazing [3]. In another study of 106 adult horses, half of the population showed a laterality where 80% preferred to advance the left limb [10]. In horses, clockwise whorls are associated with right-preferent motor laterality [8].

Motor laterality is very well described in the equestrian literature. Riders and trainers recognize that horses have an "easy side" and a "difficult side" that can manifest as a differential flexibility sometimes described as a "hollow side" and a "bulged side." There may also be differences between leads during canter e.g., one lead is more difficult for the young horse to strike off on or flying changes may be offered more readily towards the left or right. During the 15th to 17th century, the great riding masters described this phenomenon in their writings "Natural Crookedness." This natural crookedness of the horse was considered the enemy of straightness. It's an old adage that "a straight horse is a sound horse." One of the primary goals of the classical riding masters, who saw the riding hall as a gymnasium, was to create balance and straightness. Thus minimizing crookedness. Today, this is a central theme throughout the education of the horse: work to improve straightness in all gaits and exercises is included at every phase. Motor laterality has also been described in trotters and other racing horses where some horses perform less well in one direction and pull more on one of the reins.

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Marie Rhodin and Elin Hernlund have written a review article “Equestrian and biomechanical perspectives on laterality in the horse” [11] together with Agneta Egenvall, Hilary Clayton and Anna Byström to summarize the literature within this research field.

Up until now, the possible link between motor laterality (including crookedness perceived by the rider/driver) and vertical movement asymmetries assessed for lameness has never been investigated in animals. This gap is of great interest, since the diagnosis of lameness is founded on an evaluation of movement, including symmetry.

The modern objective methods for measurements of symmetry of the movement describe in detail the degree of asymmetry of several parameters based on the vertical movement in a quantitative fashion. There is however very limited knowledge of the biological significance of most of these measures. In a study of 222 riding horses in training, a remarkably high number of horses (73%) showed motion asymmetries, but whether the asymmetries were caused by pain in all horses could not be clarified [12].

The prevalence of movement asymmetry has been studied in cross-sectional studies of mature horses. Such studies do not allow investigation of pre-training movement asymmetries or temporal changes that are integral for the understanding of the origin and/or plasticity of the movement asymmetries. Therefore, longitudinal studies of two cohorts of young riding horses and trotters was initiated, and data show that 88% of the young trotters [13] and 73% of the young riding horses were present with movement asymmetries.

If sound horses present with motion asymmetries similar to lame horses, a fundamental question on the value of motion asymmetries for lameness diagnosis has to be addressed. The most obvious explanation for asymmetric movement in sound horses is the presence of motor laterality. However, such laterality has never been investigated in this context. While our previous work was focused on identifying pain and lameness, this project therefore aims at identifying natural or non-pathological explanations for movement asymmetry.

The aim of the project was to 1) describe the prevalence of motor laterality and its association to movement asymmetry in foals, young horses and high performing horses and 2) describe changes in motor laterality and associations to movement symmetry during the transition from rookie to athlete.

The specific objectives were:

• To describe motor laterality (behavioural tests) in foals as well as the presence and magnitude of movement asymmetries.
• To describe motor laterality (questionnaires) in adult high performing riding horses and associations to movement asymmetries.
• To quantify changes and investigate associations between motor laterality (behavioural tests and questionnaires) and movement symmetry in young riding horses and trotters, from novice to seasoned athlete, and describe how the first two years of training influence these parameters.

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Material and methods

Horses
The following groups of horses were included in the project:

Foals
Seventy four foals (48 foals aged 4-12 weeks of Standardbred trotter breeds and 26 foals aged 3-28 week of Warmblood breeds) were recruited to the study by direct contact with breeders in the area, as well as directed advertisements on online horse forums. Vertical movement asymmetry measurements were performed with Lameness Locator in all foals and motor laterality tests were performed in 40 of these according to methods described below. In addition, videos of limb placement during grazing were recorded in a subset of the foals (n=20).

Young Standardbred Trotters
Eighty-five trotter yearlings were recruited to from a longitudinal study and laterality was studied by questionnaires filled in by trainers/drivers, as described below. In total, 339 set of motion analysis and questionnaires was collected during different time points of the longitudinal study.

Young riding horses
Seventy-four young riding horses (2.5-3 years) were recruited from a longitudinal study. Questionnaires were used to assess laterality over time during two years resulting in over 600 set of motion analyses and questionnaires on rider-perception of laterality of the horse. In addition, motor laterality tests were performed in 42 of the horses, ten of these performed a "first stepping" test.

Elite performing riding horses
Sixty-five elite riding horses competing at national level in dressage, show jumping and eventing were recruited through personal contacts. The vertical movement asymmetry was measured and laterality assessed by the rider in a questionnaire.

Methods

Motor laterality test in foals
A modified preference test was done by a "novel object test" on the ground and observing which limb was advanced first, and by how much. This was done with the foal loose in a small enclosure along with its mare. Video recordings of foals during grazing were performed, according to a protocol developed for this project.

Motor laterality test in young horses
This was done using a standardized preference test. The trial took place in a walkway such as a trot-up aisle in the clinic or in the horses own stable. The aisle was at most 3.5m wide and at least 15m long. A bucket with food was placed at the end of the aisle and the horses were trained to approach the bucket by themselves to eat from it. The horse were released by its handler ten to fifteen meters from the bucket. The horse approached the bucket and started eating from it. Form video it was recorded when the horses "kastanj" was visible at 90 degrees indicating which hoof that advanced the most. The approach was repeated at least fifteen times and the number of times the horse put its left hoof respectively the right hoof most forward was used to calculate a laterality index, validating if the horse has a preferred limb. All approaches were recorded by portable cameras mounted to disturb the horse as little

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as possible. The handler switched which side the horse was led on approximately half of the observations.

Another preference test was performed in ten horses using a “first stepping” test. A video recording of the young horse which is led by hand on a straight line. A minimum of 15 repeats of stop to walk will be recorded. The front limb first put forward is considered the dominant limb (4). Any additional stops during the handling were scored.

Questionnaire on perceived laterality in the horse and rider/driver
Three extensive questionnaire were developed with questions regarding the laterality of the horse when handled and ridden/driven; one for elite horses, one for trotters and one for young riding horses. For each horse, differences between the two directions during lunging, differences between left and right lead during canter, perceived differences in propulsion of the hindlimbs, the “easy side” and “difficult side,” and the “hollow side” and a “bulged side” will be identified. Also, information on the riders’ handedness or other signs of motor laterality was collected. For the young trotters, questions on differences between driving directions on curves, difficulties in straightening the horse or if the horse is lugging to one side (pulling more on one of the reins) will be included (fig 1).

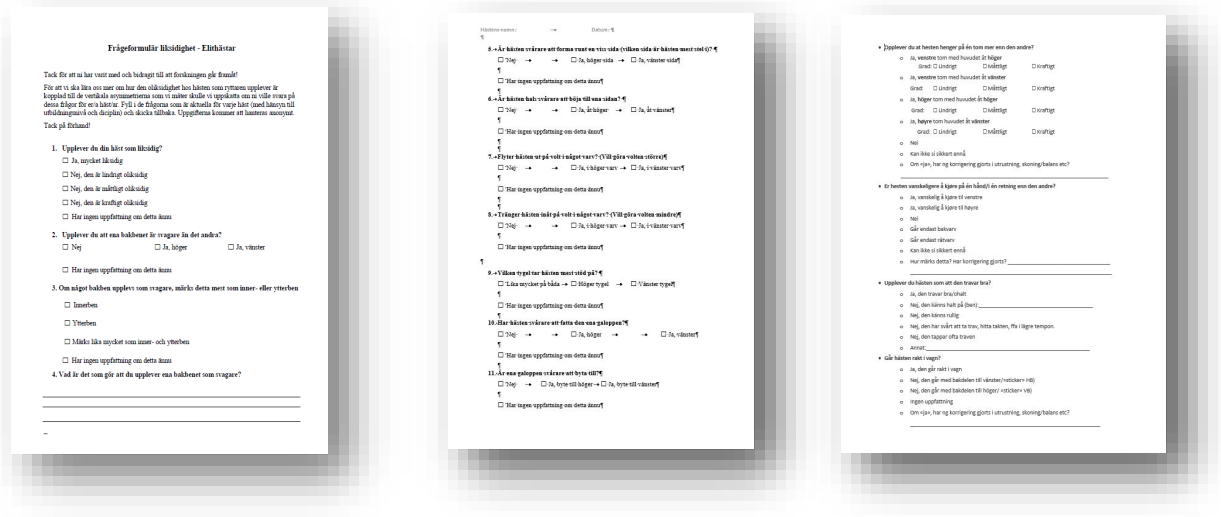

Fig 1. Parts of the three questionnaires for elite performing horses, young riding horses and young trotters. The development of the protocols was done in close collaboration with sports actives from each disciplines (highly experienced drivers and riders). This work gave interesting input to the study. An example was the obvious disagreement between two Olympic dressage riders regarding the population level laterality in horses - one saying that most horses had a strong left and the other a strong right side.

Hair whorls protocol
A protocol was developed to collect data on hair whorls for all horses participating in the project.

Sensor based lameness assessment
Lameness Locator® (LL): Motion analyses of the adult horses were performed during straight line trotting on a hard surface and on the lunge in both directions on a soft surface with a sensor-based system for lameness detection, the Lameness Locator®. Three accelerometers were mounted to a head-bumper at the poll; taped to the midline of the withers and pelvis at the level of the tubera sacrale, respectively. A gyroscope was attached to the thoracic limb.

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The vertical uni-axial acceleration was recorded and data was transmitted wirelessly from the horse to a laptop computer running the data collection software. Simultaneous video recordings was obtained during all motion analysis. To also get data from the withers, a new research option has been developed for the Lameness Locator® system to increase the amount of data available for our purposes. For the foals new algorithms for stride selection needed to be developed to identify the parts of the measurements when the foal trotted at constant speed. Data was processed with the software packages for the gait analysis system. During trot the head, and pelvis show sinusoidal movement patterns with two minima and two maxima per stride in sound horses. The minima occur during the two stance phases of the limbs and the two maxima in the suspension phases after push-off. In horses with an impact lameness, the head/pelvis show reduced vertical movement during the stance phase of the lame limb and thereby reaches a lower minimum position at mid-stance of the sound limb (HDmin/PDmin) (Fig 2). A difference between the two maximum positions (HDmax/PDmax) is also commonly seen with a lower position reached after lame limb push off. Commonly used clinical lameness thresholds were used to define the presence of movement asymmetry, absolute values >6 mm for head movement asymmetries (HDmin, HDmax) and >3mm for hindlimb asymmetry, (PDmin and PDmax) with sd lower than the mean value.

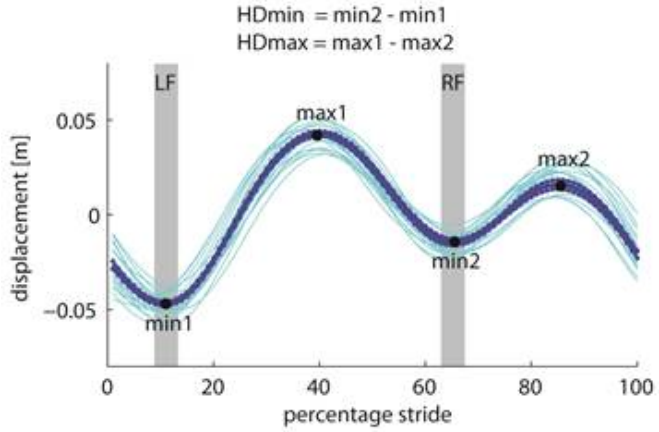

Fig 2. Vertical head movement in a horse with right forelimb (RF) lameness. The grey bars indicate left forelimb (LF) mid stance and right forelimb (RF) mid stance respectively. HDmin and HDmax are commonly used symmetry measures for lameness.

Results and discussion

Prevalence of motion asymmetries in foals

Of the foals being measured (N=74), only 7 (9%) moved completely symmetrical using the definition described above. Overall, many of the foals in this population showed right forelimb asymmetries (46 %) while a significantly less portion have a left forelimb asymmetry. Thirty-six percent of the foals had an asymmetry originating from the left hindlimb while only 26 % from the right hind limb (Fig 4).

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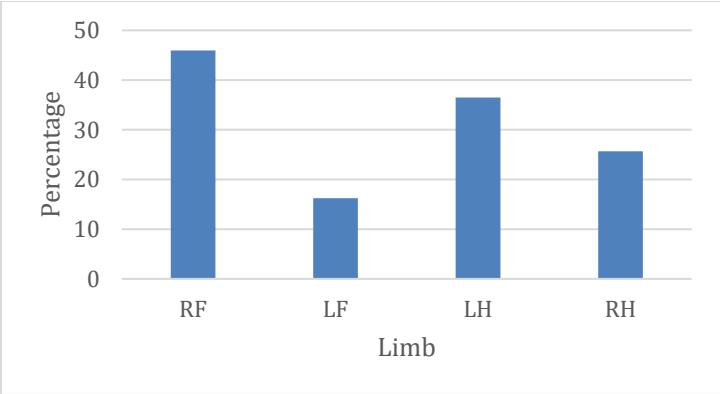

Fig 3. Distribution of vertical movement asymmetries according to limb.

Motor laterality in foals

All data have not been analyzed in detail yet, but preliminary results of a subset of 20 foals are available. Of these, eight were excluded from the study due to important findings on the clinical exam or due to problems with motion analysis measurements. Of these foals, only four showed a significant laterality, three to the right and one to the left. There were no apparent correlation between asymmetry values and motor laterality, significance testing has to await the final analyses.

Foal	Breed	Laterality	z-test	Asymmetry
1	STB	-58.6	-3.2	HDmax RF
2	STB	25.0	0.7	no
3	SWB	-28.6	-1.1	no
4	SWB	-10.0	-0.4	no
5	SWB	-40.0	-1.3	no
6	SWB	75.0	2.1	no
7	SWB	-25.0	-0.7	HDmin LF
8	STB	-20.0	-0.6	PDmax LH
9	SWB	0.0	0.0	no
10	SWB	71.4	3.3	no
11	SWB	62.5	2.5	HDmin LF
12	SWB	-33.3	-1.7	HDmax RF

Table 1. Laterality and symmetry classifications of the twelve foals. Left Front (LF), Right Front (RF) Left Hind (LH) and Right Hind (RH).

Motor laterality in young horses

Of the 32 young horses who underwent the motor laterality tests, only six showed a z-value above 1.96, meaning only 19% of the studied population showed a significant laterality during these test. Two of these horses (6 % of the population) had a significant laterality to the left and four horses (12% of the population) showed laterality to the right side. The results of the feeding tests and LL-measurements are presented in Table 2.

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Horse	Laterality	z-test	HDmax	HDmin	PDmax	PDmin	WDmax	WDmin
1	33.3	1.3	5.4	2.2	-1.5	6.1	4.7	12.4
2	88.9	3.8	**-15.0**	2.6	1.7	**10.3**	-14.6	16.7
3	12.5	0.5	-17.4	-10.9	5.8	7.0	-16.6	2.7
4	-6.7	-0.3	8.3	-32.4	8.8	-9.4	-2.4	-6.8
5	-12.5	-0.5	-0.7	2.5	-9.5	-0.4	16.8	2.0
6	100.0	3.9	15.5	-14.9	-6.2	6.2	-3.6	-12.5
7	0.0	0.0	12.3	-13.4	2.8	-5.0	6.6	6.2
8	20.0	0.8	12.7	3.1	9.0	12.9	1.4	-2.6
9	-73.3	-2.8	1.0	**-10.1**	**3.5**	0.9	-10.3	-1.9
10	20.0	0.8	-19.3	-9.7	1.8	11.6	-2.1	0.3
11	-37.5	-1.5	-0.4	-21.8	6.3	4.7	-1.1	3.2
12	6.7	0.3	-8.7	11.6	8.1	-0.1	8.0	5.5
13	-20.0	-0.8	8.9	9.7	15.4	-5.9	-5.7	-6.2
14	-29.4	-1.2	-15.3	-12.3	-9.3	4.3	4.1	3.9
15	100.0	3.9	**-12.5**	-4.1	1.6	**-2.1**	-4.1	8.7
16	33.3	1.3	7.3	-17.3	-8.8	2.7	-0.6	-5.7
17	46.7	1.8	15.2	-3.8	-0.1	-5.4	-5.4	-2.0
18	-17.6	-0.7	-8.7	-15.9	-0.8	0.0	-6.6	3.7
19	-6.7	-0.3	-20.1	7.6	7.5	2.6	-12.1	1.5
20	-5.9	-0.2	-5.8	12.3	-5.8	7.6	3.8	3.4
21	46.7	1.8	35.4	18.9	8.2	10.5	9.2	2.7
22	-6.7	-0.3	-1.6	2.4	-6.6	3.6	-4.4	1.2
23	-60.0	-2.3	2.7	**14.1**	-5.6	**7.2**	4.2	6.9
24	-20.0	-0.8	11.0	-7.0	-1.6	0.1	8.0	-1.9
25	-14.3	-0.5	6.2	-30.1	14.5	-2.7	-7.1	-3.8
26	25.0	1.0	3.4	-17.5	-1.0	10.5	3.2	-0.8
27	25.0	1.0	-5.0	-14.6	3.1	0.8	-9.1	-3.0
28	87.5	3.5	**-10.7**	2.3	0.0	**6.9**	-2.2	-1.9
29	10.0	0.4	-17.6	15.7	0.3	-0.4	-2.5	-3.9
30	30.0	1.3	-6.2	-0.7	0.9	-1.3	-8.4	3.2
31	0.0	0.0	29.0	15.4	-3.7	4.3	-1.9	3.6
32	-15.8	-0.7	-15.6	-17.5	3.2	-1.0	-7.4	23.6

Table 2. Laterality and asymmetry measurements of 32 young horses, age xx years. Horses with laterality to the left are marked blue and laterality to the left is marked yellow. Negative symmetry measures indicate a left sided asymmetry and positive values indicate a right sided asymmetry.

When plotting the vertical asymmetry values against the laterality score, a linear regression analysis shows little to no correlation (R squared < 0.05) for both front and hindlimb asymmetry, Fig 4. This indicates that the laterality score is not associated directly with any vertical motion asymmetries in this population.

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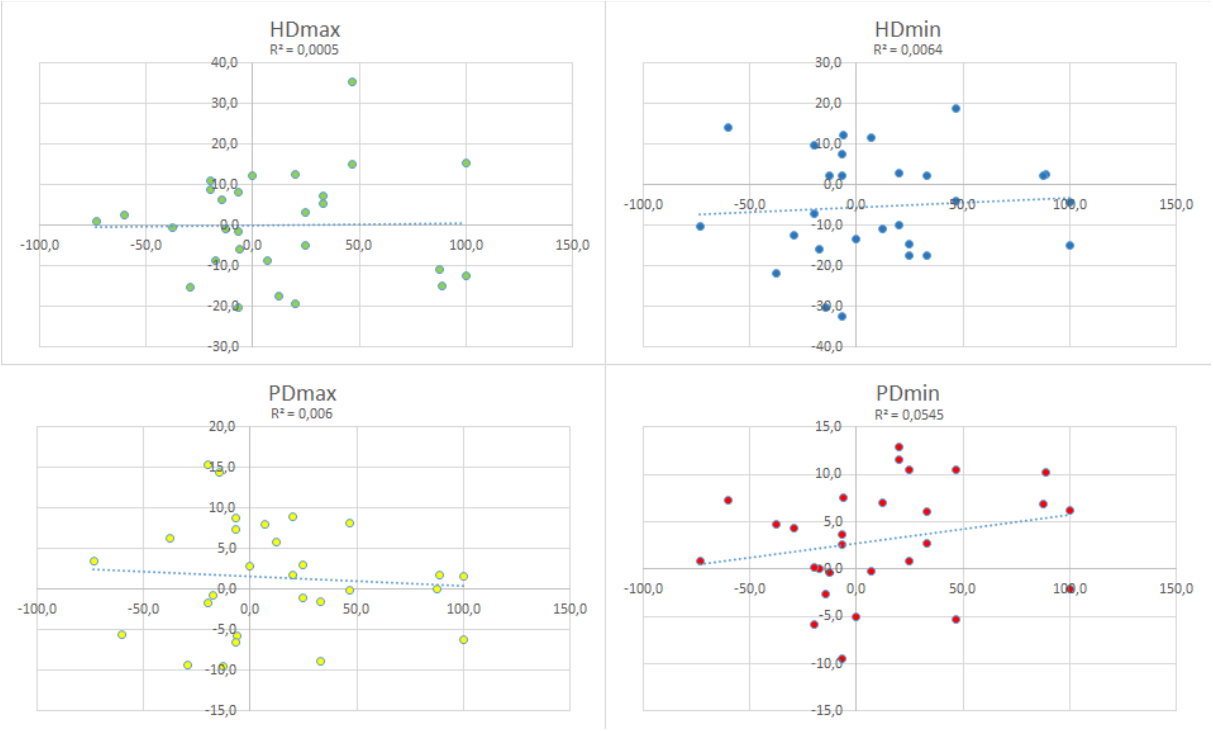

Figure 4. Linear regression analysis of laterality score and vertical asymmetry

This is done in table 2. In this population, only six horses showed significant laterality. It is interesting to note that the prevalence of significant laterality in the young horses tested is approximately the same as in the foals tested.

Horse	Laterality	z-test	(A)symmetry
2	88.9	3.8	HDmax Left front and PDmin Right hind
6	100.0	3.9	HDmin LF, HDmax RF, PDmin RH and PDmax LH
15	100.0	3.9	HDmax LF
28	87.5	3.5	HDmax LF and PDmin RH
9	-73.3	-2.8	Symmetrical
23	-60.0	-2.3	HDmin RF and PDmin RH

Table 3. Laterality score and the relevant vertical asymmetries for each horse. Left Front (LF), Right Front (RF) Left Hind (LH) and Right Hind (RH).

As shown in Table 3, all horses with a right sided laterality (blue) also had a motion asymmetry on the left forelimb. For the horses with a left sided motor laterality (yellow), only one of the two horses showed vertical movement asymmetries on right hind and right front. This may indicate that in these young horses a significant laterality would affect the contralateral forelimb. However, a larger sample size, consisting of horses with a high degree of laterality, would be needed to test this statistically. Both horses with left-sided and right-sided motor laterality showed a motion asymmetry on the right hind. No conclusions of these asymmetries can be drawn.

For the “first step” test in twelve horses, two of the horses showed a left and only one a right limb laterality.

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Perceived laterality by owners of young riding horses
Due to the enormous amount of motion data collected in the longitudinal study data analysis is still in progress. Data on the rider perceived laterality of the horses has been collected and ready to analyze as soon as all asymmetry data is analyzed.

Young trotters
Due to the enormous amount of motion data collected in the longitudinal study, data analysis is still in progress. Data on the driver perceived laterality of the horses is collected and ready to analyze when asymmetry data is analyzed.

High level performing riding horses

The association between the rider-perceived laterality and objectively measured summed asymmetry parameters per horse (with values for head divided by 2) was tested using a Kruskal-Wallis test. No significant association was found (p=0.51). The parameters used to describe vertical movement asymmetries of head pelvis and withers are shown to be associated to horizontal and vertical unloading of the lame limb. It is possible that the *shape* of the vertical displacement curve would reveal more associations to the laterality than the time discrete values that ae used for lameness assessment (where positive and negative peaks are compared within each stride). The shape of the curve might explain more about how a limb produces forward and upward propulsion which might be particularly interesting for the hind limb motor asymmetry that is described by riders.

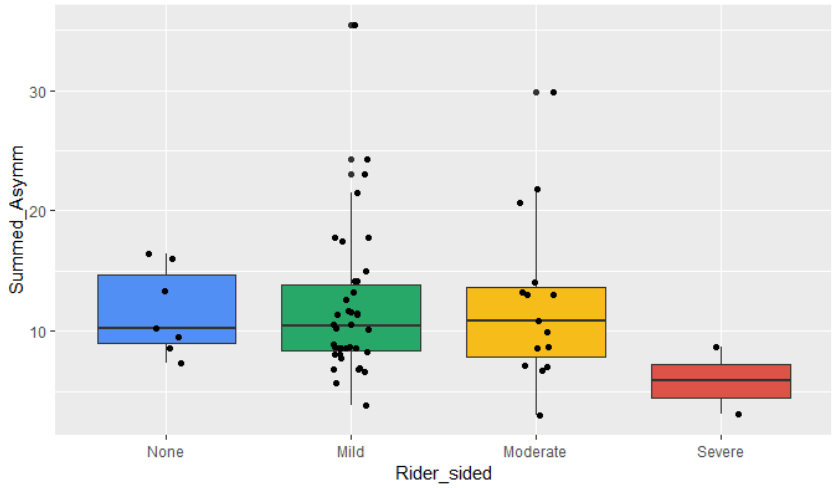

Fig. 5. The summed asymmetry vertical movement asymmetry for head and pelvis was calculated for each horse. Horses were divided into categories describing their degree of motor laterality assessed by the rider. No significant association was found between the rider perceived laterality and objectively measured summed vertical asymmetry (Kruskal-Wallis, p=0.51).

Conclusions

We conclude that significant motor laterality is rare in young foals using our methods. No associations between motor laterality and movement asymmetries can be detected, but data analysis on a larger data set is in progress for later final conclusions.

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The prevalence of significant motor laterality in young horses is low using preference test. Further data analysis will show if there is an association between rider-perceived laterality of the horse and movement asymmetries and the effect of training and development over time.

Riders perception of laterality in elite horses seems unrelated to objective measures of vertical movement asymmetries.

Relevance for the practical horse sector incl. recommendations

This project has added substantial knowledge on the concept of laterality – the preferred use of one side of the horse. Our results show that significant sidedness is relatively rare in foals and young horses even though movement asymmetries are common, and if it is present, it is probably not associated to asymmetry of the movement. There is still some data that will be analyzed for a final conclusion.
These results put general emphasis on the professional quality of the lameness examination. Many horses, even young horses are moving asymmetrically. Objective movement analysis can therefore not be used for diagnosis of lameness, it is an extremely sensitive indicator of source of asymmetry, but findings should be verified by analgesic blocks.
When riders talk of a weak and a strong side of a horse, this has no obvious association to its vertical movement asymmetry. This finding has some relevance for further understanding of the fact that many ridden horses are moving asymmetrically, and a proportion of these are indeed lame without the riders notice. Our results has indicated that natural sidedness is not an explanation for this.

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Part 3: Result dissemination

State all result dissemination from the financed project into the appropriate section, including information as indicated. Additional rows can be added to the table.

Scientific publications, *manuscript*	E. Hernlund, E. Persson-Sjodin, J. Lundblad, T. Pfau, Pia Haubro Andersen, M. Rhodin. *Vertical movement symmetry and rider perceived laterality in elite riding horses.*
Conference publications/ presentations	E. Hernlund, E. Persson-Sjodin, Britt Coles, T. Pfau, Pia Haubro Andersen, M. Rhodin (2018). *Vertical movement symmetry and rider perceived laterality in elite riding horses.* International Conference on Equine Exercise and Physiology, Australia nov 2018
Oral communication, *to horse sector, students etc.*	*Är hästen halt?- - senaste rörelseforskningen vid SLU* 191021, Hagmyrens travbana, trotting horse sector, https://www.facebook.com/arenahagmyren/posts/2731634040264297
	Rörelseasymmetrier hos hästar- normalt eller tidigt tecken på hälta? Horse sector, 190327, Agria, Strömsholm
	Objective tools for motion analysis in horses, 200910, Rolexstipendiater (international show jumper riders),SLU
	Vad är friskt och vad är sjukt? Senaste nytt inom rörelseforskning på häst, 191111, SVA/SLU-anställda, Ultuna.
Student theses	*Camilla Frisk, Marie Rhodin, Emma Persson Sjödin, 2017, Relationship between laterality and vertical movement asymmetries in horses, Masters thesis (http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-s-9570)*
	Hanna Mandinger, Marie Rhodin, 2019, Prevalence of movement asymmetry in foals and association to laterality, Masters thesis. (http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-s-10689)

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