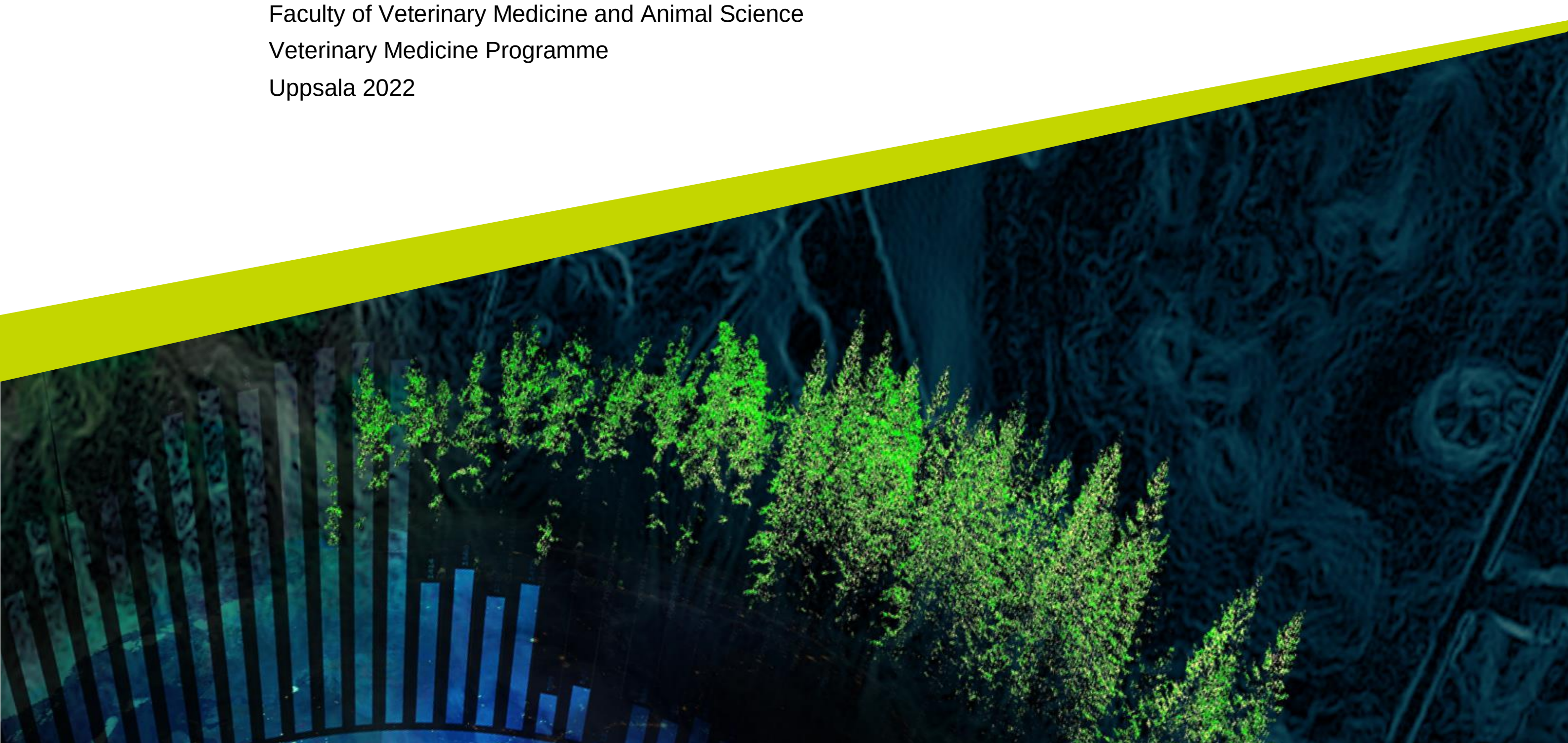
Motion asymmetry in Swedish riding school horses

–Association to management factors

Michelle Jobusch

Degree project/Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Veterinary Medicine and Animal Science
Veterinary Medicine Programme
Uppsala 2022



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Credits:	30 credits
Level:	A2E
Course title:	Independent project in Veterinary Medicine
Course code:	EX0869
Programme/education:	Veterinary Medicine Programme
Course coordinating dept:	Department of Anatomy, Physiology and Biochemistry
Place of publication:	Uppsala
Year of publication:	2022
Keywords:	Orthopaedic Health, Lameness, Movement symmetry, Riding School Horses, Mobile phone application, Management Factors, Horse factors

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Abstract

Orthopedic disorders and injuries have a huge impact on horses, globally as well as in Sweden, and is a common reason for euthanasia in equine veterinary practice. Lameness is the most common sign of orthopedic pain and does not only come with welfare issues but also huge economic consequences. Riding school horses represent an important part of the Swedish horse industry, and 10 700 horses were active in Swedish riding schools in 2019. Previous studies found differences in orthopedic health status between riding schools, which were suggested to be associated with the riding schools' management and individual horse factors. The purpose of this master´s thesis is to further describe motion asymmetry (by objective evaluation), management factors, and horse factors in Swedish riding school horses.

Four of the 14 contacted riding schools participated in the current study, with a total of 76 horses. Management and horse factors were investigated by questionnaires answered by the riding school managers. Motion symmetry was objectively measured with the markerless smartphone app *Sleip AI*, which uses artificial neural networks to identify vertical motion asymmetry. The horses were recorded trotting in-hand in a straight line on packed dirt 30 meters two times back and forth (approximately 120 meters in total). Each horse was measured on two or three different occasions, with 7-8 days in between. Lameness metrics; HDmin, HDmax, PDmin, and PDmax were extracted from each horse's asymmetry measurement. A representation of the horse's total amount of motion asymmetry was calculated by adding these four values together from each measurement occasion and then a mean value from all measurement occasions was calculated. The mean total asymmetry was used in descriptive statistics and for hypothesis testing. A horse was defined as having a relevant total motion asymmetry when the value was >0.75. This was based on clinical experience. Hypothesis testing was performed by grouping horses based on age, gender, number or hours of riding lessons per week, months since the acquisition, previous lameness, summer rest, and type of activity, and by using a double-sided heteroscedastic t-test to investigate differences in total motion asymmetry between groups. The level of significance was set to $p< 0.05$.

Results showed that in the four riding schools the total motion asymmetry ranged from 0.30 to 2.20, and 50 of the 76 horses (66%) were considered to have relevant (>0.75) motion asymmetry. A significant difference in total motion asymmetry was found between horses in groups based on the amount of summer rest in one riding school ($p=0.004$), the number of riding lessons per week ($p=0.017$ and $p=0.034$), and previous lameness ($p=0.02$) for all riding schools together. No significant difference in total motion asymmetry was seen between horses in groups which were based on hours of riding school lessons, type of activity, age, gender, breed, and time since acquisition. But through descriptive statistics, (non-significant) differences in total motion asymmetry within the studied horse sample were seen between subgroups based on the type of activity, age, and time since acquisition. Further, variance in the lameness metrics HDmin, HDmax, PDmin, and PDmax was observed (but not further investigated) between measurement occasions. Some horses were observed to repeatedly show asymmetry from the same limb, while in others the origin of the asymmetry differed between the measurement occasions.

The results from this study indicate that differences in riding school horses' motion asymmetry can be associated with management and horse factors. The results support that specific attention should be given to the amount of summer rest, the number of riding lessons per week, and previous lameness, but likely other management- and horse factors can be of importance too. This agrees with previous literature concerning riding school horses’ orthopedic health status in Sweden. With that being said, additional studies are needed in this field to draw robust conclusions. Further studies should include larger study material and follow the horses' motion symmetry over a longer period of time. Also, more management and horse factors that possibly can affect the horses' motion symmetry should be included.

Keywords: Orthopaedic Health, Lameness, Movement symmetry, Riding School Horses, Mobile phone application, Management Factors, Horse factors

Table of contents

List of tables

List of figures

Abbreviations

HDmax	maximum head difference
HDmin	minimum head difference
PDmax	maximum pelvic difference
PDmin	minimum pelvic difference

1. Introduction

Locomotor problems are the most common diagnosis in equine veterinary practice in Sweden as well as globally (Kaneene *et al.* 1997; Penell *et al.* 2005; Egenvall *et al.* 2006). Joint problems cause lameness and are the most frequent reason for veterinary care and euthanasia in Sweden (Egenvall *et al.* 2005; Penell *et al.* 2005). Globally lameness is the most common reason for euthanasia (Nagy *et al.* 2014). Furthermore, locomotor problems in horses have massive economic consequences (USDA Animal Plant Health Inspections Service. 2001; Uprichard *et al.* 2014) and are causing the greatest economic loss for the equine industry (Thal 2016).

Sweden is Europe´s second most horse dense country (Swedish Equestrian Federation 2019). About 10 700 horses were active in Swedish riding schools in 2019, which represent an important part of the Swedish horse industry. A study of the orthopedic health status of riding school horses by Egenvall (2010) found that locomotor problems accounted for 70% of the insurance claims. Another study by Egenvall *et al.* (2009) discovered that there was a difference in orthopedic health status between Swedish riding schools. Egenvall *et al.* suggested that different management and individual horse factors could be associated with this. Since lameness or locomotor problems play an important role in Swedish riding horses and should be further investigated using objective techniques for lameness evaluation.

This master´s thesis aimed to describe motion asymmetry in Swedish riding school horses by measuring horses objectively over a three-week period and to describe management factors and individual horse data by using a questionnaire. We hypothesize that management factors associated with high insurance claims for lameness from earlier studies (less manager and staff experience/education, decreased summer rest, and increased level of activity) would be associated with a larger degree of asymmetry on a group and/or horse level, and that horse factors (increased age, increased months since acquisition and previous lameness) would be associated to increased asymmetry on a horse level.

2. Literature review

2.1. Orthopedic health in Swedish riding school horses

Riding school horses represent an important proportion of the Swedish horse industry and differ from privately owned horses in a few aspects (Swedish Equestrian Federation 2019). Generally, Swedish riding school horses have a more homogenous use and activity level compared to privately owned horses (Egenvall *et al.* 2009). Furthermore, managers of riding schools have on average more equestrian training and experience compared to private horse owners (Egenvall *et al.* 2009). Statistically, one of four managers of riding schools is educated as a horse trainer, horse judge, or in the field of horse nutrition (Kielén *et al.* 2018).

Lameness as a sign of locomotor problems play an important role in Swedish riding school horses. In a study by Egenvall *et al.* (2009), locomotor problems accounted for 70% of the insurance claims in riding school horses. Also, Yngvesson *et al.* (2019) found that the most common health issue in riding school horses was lameness followed by skin lesions. Group-level orthopedic health status has been found to vary between different riding schools, and individual horse factors and different management strategies are suggested to be associated with this (Egenvall *et al.* 2009, 2010).

2.1.1. Management

Manager and staff experience

Few studies focus specifically on management concerning orthopedic health status in Swedish riding school horses. Egenvall *et al.* (2010) found significant differences in orthopedic health status between riding schools when comparing high (HIU) and low insurance utilization (LIU) riding school (insurance utilization was used as an indirect measurement for lameness prevalence). The most likely reason was that riding schools differed in multifactorial management strategies which in turn helped prevent orthopedic injury and to keep horses longer. Multifactorial management strategies could include variations in staff experience and/or level of training.

Later, in a field study by Lönnell *et al.* in 2012, it was additionally supported that differences in management strategies could be associated with orthopedic health status and injury. The variation in equine management factors between riding schools with high (HUIO) vs. low (LUIO) utilization of insurance for orthopedic injury was studied. The median work experience of managers was 10.0 years (HUIO) respectively 18.5 years (LUIO), with significantly more riding schools in the LUIO group having managers with over 11 years' experience. Riding schools with chief instructors with a level 3 instructor's exam and/or competition experience on advanced level were 11% (HUIO) respectively 70% (LUIO).

Summer rest and level of activity

Summer rest and level of activity (the number of hours the horse is riding) are also two management factors of importance. Too little rest and intensive periods of training can negatively affect the horse's locomotor apparatus and lead to stress-related injuries (Ross 2011b). This is particularly seen in racehorses but can affect all horses. The number of weeks on summer pasture for Swedish riding school horses was approximately between 3-5 weeks (Yngvesson *et al.* 2019). In the study of Lönell *et al.* (2012) the median for summer rest was 3.7 (HUIO) respective 5.3 (LUIO) weeks, indicating that a longer summer rest could result in less orthopedic injury. Unpublished data in Egenvall *et al's.* study (2010) also indicates that the summer rest of ≥4 weeks protects the horse from wastage. When it comes to the level of activity, on average riding school horses was ridden between 8-12 hours per week (Yngvesson *et al.* 2019). In the study of Lönell *et al.* (2012) lessons per week were 15.6 (HUIO) respectively 14.1 hours (LUIO), which is not a significant difference.

Activity type and weight limits for riders

Two other important management factors to address are the type of activity the horse is performing and weight limits for the rider. Different types of activity, such as dressage or show jumping, will affect the horses' locomotion apparatus differently (Murray *et al.* 2006; Ross 2011b). For example, will dressage horse most commonly injure the suspensory ligament in hind limbs while elite showjumpers have a higher risk of injury of the superficial digital flexor tendon or the distal deep digital flexor tendon in the forelimbs (Murray *et al.*, 2006). Regarding riders' weight, a study showed that large riders can induce temporary lameness as well as behavioral changes consistent with musculoskeletal pain (Dyson *et al.* 2020). Inappropriate rider size also has consequences for the welfare of the horse (Clayton *et al.* 2015).

Housing, pasture turnout, and riding surface

Riding school horses can be housed either in groups or kept in box housing/ conventional tie-stall (Kielén *et al.* 2018). In 2016 the majority (over 90%) of the riding schools and trail riding companies kept their horses in individual boxes and 35% still used tie-stalls to some extent. Of the riding schools, 13% used group housing. The occurrence of injuries and lameness was found to be similar between boxes/tie-stalls and group housing (Yngvesson *et al.* 2019).

Pasture turnout is important for the horses' health and wellbeing. Horses having pasture turnout is an important part to avoid stereotypic behaviors (Sarrafchi & Blokhuis 2013; Hockenhull & Creighton 2015), but also, has a positive effect on the horses' fitness and strengthens the locomotor apparatus (maintaining healthy bone mineral content) (Bell *et al.* 2001; Graham-Thiers & Bowen 2013). Also, the arena surface affects the orthopedic health in riding horses (Egenvall 2013, Murray *et al.* 2010**)**, similar to the track surface affecting racehorses (MacKinnon *et al.* 2015). For example, a greater proportion of stress fractures, hindlimb/pelvic, and tibial stress fractures were found in the racehorses training on synthetic surfaces compared to dirt surfaces. Meanwhile, in dressage arenas, dressage horses had a lower risk of injury when ridden on wax-coated or sand and rubber surfaces compared to sand, sand and PVC, woodchips, or grass when studied using a questionnaire-based inquiry (Murray *et al.* 2010).

2.1.2. Horse factors

As mentioned before, a previous study by Egenvall (2009) suggested that also individual horse factors could be associated with differences in orthopedic health status. For example, horse factors can be age, gender, breed, time at the riding school since the acquisition, and previous lameness.

Age

Orthopedic conditions, such as osteoarthritis and navicular disease, that are generally age-related or progressive, are particularly seen in older horses (Ross 2011b). The number of clinical findings in an orthopedic examination increased with the riding school horses´ age and were most common in the oldest age group (Egenvall *et al.* 2010). In the same pilot study by Egenvall *et al.*, which compares 4 riding schools with high insurance utilization (HIU) and 4 riding schools with low insurance utilization (LIU), the horses in the LIU group were overall older. The mean horse age by riding school varied from 8.3 (HIU riding school) to 15.6 (LIU riding school). The study by Lönnell *et al.* (2012), which compares riding schools with high (HUIO) vs. low (LUIO) utilization of insurance for orthopedic injury, concluded the mean horse age was 11.3 (HUIO) respectively 12.6 (LUIO) years.

Gender and breed

The proportion of geldings was higher than mares in riding school horses. One study found that 63% were geldings (Egenvall *et al.* 2010) and another study found that 38% were mares (Lönnell *et al.* 2012). No difference between geldings and mares was observed in terms of veterinary care and locomotor problems (Egenvall *et al.* 2009). These results are in agreement with the literature where most lameness conditions affect the different sex with similar frequency (Ross 2011b).

The breeds of horses used in Swedish riding schools are mainly composed of Swedish and imported warmbloods and ponies, native breeds, and crossbreds (Egenvall *et al.* 2009; Kielén *et al.* 2018). In the study by Egenvall *et al.* (2010) the proportion of different breeds was investigated in the HIU- and LIU-group. Swedish warmbloods constituted 19% of HIU and 56% of LIU, other Swedish or of unknown origin 22% of HIU and 13% of LIU, and imports 58% of HIU and 30% of LIU. Lönnell *et al.* (2012) found also that there was a higher proportion of Swedish warmbloods horses in the LUIO group (although not statistically significant), with a median of 49% (LUIO) respectively 29% (HUIO). Normally most lameness conditions affect all breeds (Ross 2011b). The greatest impact on lameness distribution, which indirectly can be influenced by breed, is primarily the type of sporting activity. However, one previous study found differences in riding school horses regarding the breed. Horses had compared to ponies higher risk of at least one veterinary-care event and mortality (Egenvall *et al.* 2009). Compared to other breeds, Swedish warmbloods´ with previous locomotor veterinary-care claims, had a higher risk of life claim because of locomotor problems.

Acquisition, age of entry, and previous lameness

Generally, the meantime passed since horse acquisitions in the LUIO/LIU riding schools was higher compared to the HUIO/HIU riding schools, indirectly indicating that horses stayed longer and had fewer locomotor problems in the LUIO/LIU group. The mean time since the acquisition was 5.7 (LUIO) compared to 3.5 years (HUIO) (Lönnell *et al.* 2012). In the study of Egenvall *et al.* (2010), generally, the meantime since acquisition would also be higher in the LIU group compared to the HIU group. All LIU-groups had a mean time since acquisition ≥5.3 years. There was no difference found in the horses' age at acquisition between the two groups.

The horses´ age of entry combined with previous locomotor veterinary-care claims influences the horses´ life claims negatively (Egenvall *et al.* 2009). For horses with previous locomotor veterinary-care claims the risk of life claim because of locomotor problems increased with each year of age calculated from the age of entry to the riding school. This also brings us to another horse risk factor which is the horse´s past history. Horses previously diagnosed with locomotor problems had an increased risk of new locomotor injury compared to horses with no history of locomotor problems (Axelsson *et al.* 2001; Ross 2011b; Georgopoulos & Parkin 2016).

2.2. Lameness in the horse

Lameness or locomotor problems is the most common disease category in equine veterinary practice (Kaneene *et al.* 1997; Penell *et al.* 2005; Egenvall *et al.* 2006). While the clinical manifestations of lameness are well known, a perfect definition of the term is rather difficult (Ross 2011a). Locomotor problems are complex, and can be primary or secondary/compensatory, acute or chronic, and involve nearly any anatomic region within a limb (Ross 2011a; Thal 2016). Additionally, they can have various causes and be difficult to localize (Penell *et al.* 2005; Ross 2011a).

2.2.1. Lameness and motion asymmetry

Defining lameness is a challenge, but it can be described as a condition where the horse is incapable of normal locomotion (Ross 2011a; Thal 2016). Lameness is generally distinguished by an inability to maintain a normal gait and can be manifested by an asymmetry in movement, visible incoordination or weakness, or inefficient motion of the limbs. Exceptions exist, for example, horses with bilateral lameness can still be symmetrical in motion when moving in a straight line (Baxter *et al.* 2020).

With that said, researchers stress that it is important to not equal lameness to asymmetry. While lameness can cause motion asymmetry, motion asymmetry doesn´t necessarily mean the horse is lame (van Weeren *et al.* 2017). In a study by Rhodin *et al.* (2017), motion asymmetries were found in riding horses that were considered sound by their owners. 73% of the 222 horses that were measured objectively were asymmetrical in movement (according to the limits set by the manufacturer). In another study, standardbred yearlings were objectively measured during trot in-hand, where most of the horses showed mild asymmetry (Kallerud *et al.* 2021). 93% of the 103 horses were found asymmetrical in their movement (according to the manufacturer's recommended thresholds based on repeatability levels). Further, motion asymmetry can vary over time (Hardeman *et al*. 2019).

2.2.2. Assessing motion asymmetry

Subjective evaluation

Subjective evaluation of lameness is a standard of practice that is done by a veterinarian watching the horse in motion (Keegan *et al.* 2010). Evaluation can be done with the horse trotting in a straight line, on the lunge or under the saddle, on soft or hard ground (Hardeman *et al.* 2019; Baxter *et al.* 2020). On hard ground, most lameness conditions will be more apparent (Ross 2011a). A sound horse will move symmetrically, which means with equal movement amplitude in the limbs, head, and torso during the right respectively the left halves of the step (Keegan 2005; Ross 2011a). A horse with a lame limb will move asymmetrically, which means with non-equal movement amplitudes produced by the right and left limbs in the fore- and hindlimb pairs. This asymmetry is what the veterinarian assesses when evaluating the horse in motion, and can for example appear as a head bob when a horse is lame on a front limb (Keegan 2005). As already mentioned, horses with bilateral lameness may appear symmetric on the straight line and can therefore be hard to evaluate correctly (Baxter *et al.* 2020). Furthermore, studies have shown that subjective evaluation is not reliable, especially when evaluating mild lameness (Arkell *et al.* 2006; Keegan *et al.* 2010; Starke & Oosterlinck 2019).

Objective assessment tools

Gradually, objective gait assessment is becoming a standard tool for lameness examination in equine practice (Serra Bragança *et al.* 2018). Objective gait assessment overcomes some of the limitations with subjective evaluation, providing unbiased information and identifying mild lameness or motion asymmetry. Different methods are used for objectively assessing lameness in horses (Bosch *et al.* 2018). Assessment can be done by measuring either force (kinetics) or motion (kinematics) (Serra Bragança *et al.* 2018). Kinematics studies the motion of the body segments (Kaufman & An 2017). The horse's kinematic data can be collected, measured, and quantified objectively, to evaluate for deviation or asymmetry in movement (Buchner *et al.* 1996). This is similar to subjective evaluation, where the observer is investigating the horse's motion and looking for signs of motion asymmetry in the lame horse (Ross 2011a). Objectively horse's motion symmetry can be evaluated by measuring the movement amplitudes in the limbs, head, and pelvis when the horse is trotting (Keegan 2005; Ross 2011a). Also, the movement symmetry in the withers can be measured, but studies found that head and pelvic measurements were better at detecting mild lameness (Buchner *et al*. 1996; Uhlir *et al*. 1997)

In detail, when a horse is trotting, its head and pelvis will move up and down two times during each stride cycle (one time for the left and one time for the right side)

(Kramer & Keegan 2014). The head reaches its vertical maximum upper position (HDmax) just before the hoof of one forelimb contacts the ground, and the minimum position (HDmin) when the same forelimb has reached near midstance. Meanwhile, the pelvis vertical minimum position (PDmin) is reached during the middle of one of the back limb's stance phases, and the maximum position (PDmax) at the end of the phase. As mentioned before, a lame horse will move asymmetrically with unequal movement amplitudes in the limbs, head, and torso during the right respectively the left halves of the step (Keegan 2005; Ross 2011a). In other words, a horse with forelimb lameness will have a difference between the two (left and right) vertical head maximum (HDmax) and minimum (HDmin) positions, while a horse with hindlimb asymmetry will have a difference between the two pelvic maximum (PDmax) and/or minimum (PDmin) positions (Kramer & Keegan 2014). This difference in the movement amplitudes can be used by objective tools to distinguish horses' motion symmetry on the front- respective hindlimbs (McCracken *et al*. 2012).

One of many tools to measure motion asymmetry objectively is the new smartphone app *Sleip AI*. This app will, with the help of artificial neural networks, identify vertical motion asymmetry in horses using markerless tracking (Hernlund *et al*, submitted 2021). The system has been validated for straight line measurements against a state-of-the-art motion capture system. *Sleip AI* gives measurements of HDmin, HDmax, PDmin, and PDmax. Increased HD- or PDmin values indicate an impact lameness, while increased HD- or PDmax indicates push-off lameness. Other kinematic analysis systems such as Equinosis *Lameness Locator* (an inertial sensor system) identified gait asymmetry at a lower level of sole pressure than 3 equine veterinarians, showing how objective assessment can overcome the limitation with subjective evaluation and identify mild motion asymmetry (McCracken *et al.* 2012). In another study, Equinosis *Lameness Locator* even found mild lameness more easily than force plates (Donnell *et al.* 2015), likely since force plates generate data from very few strides per run. Further, kinematic analysis techniques are considered reliable enough to warrant clinical application (Serra Bragança *et al.* 2018).

3. Materials and methods

3.1. Riding schools and horses

The data collection took place from the 27th of September to the 3rd of November 2021. The target population was horses and ponies in Swedish riding schools. A convenience sample of riding schools was recruited based on their proximity to Lund, Skåne, Sweden. A total of 14 riding schools that were found through the Swedish Equestrian Federation’s (Svenska Ridsportförbundet) homepage were selected, contacted, and invited to participate, with the inclusion of four yards approximately within one hour away with public transportation. Riding schools with horses which were also used as private riding horses part of the time were excluded from the study. In total four riding schools accepted participation in the study. Before measurements started the riding school signed documents with consent (Appendix 1,2).

Riding school horses and ponies were chosen with the criteria that they were considered healthy by the riding school staff and not given any medication within two weeks from the first day the measurements started. Horses or ponies that according to the riding school showed serious signs of stress were excluded from the study for safety reasons. This resulted in a total of 76 horses (see Table 1 for distribution) participating from the four riding schools.

3.2. Objective motion asymmetry measurements

Every riding school had their horses measured two or three times, with 7-8 days between each occasion. At three riding schools, the horses were measured three times and in one riding school, the horses were measured twice (Table 1). No horses dropped out. Motion asymmetry was measured using the same tools and procedure each time. The horses were trotted in hand on packed dirt in a straight line for approximately 120 meters in total (30 meters two times back and forth). Recordings were made with an iPhone 12 Pro placed on a tripod at eye height, using the phone application *Sleip AI.* This phone application incorporates neural networks and automated signal processing for analysis of the motion symmetry of horses. The recorded video is transferred to *Sleip AI's* cloud servers, where neural networks recognize the horse in the image, follow its activity, and perform markerless tracking of multiple body segments while the horse is trotted. The analysis takes approximately 2.5-3 minutes, and values for HDmin, HDmax, PDmin, and PDmax were extracted for each run.

Table 1 Distribution of the number of riding school horses per each riding school (1-4), and the number of measurements per each riding school.

Riding school	Number of horses	Number of measurements
1	16	3
2	28	3
3	16	3
4	16	2

3.3. Management and horse questionnaires

To gather information about the riding school and the horses, two questionnaires were used. The questionnaires were sent by email. The riding school's manager filled out the questionnaire about management strategies (a Microsoft Word document) and horse information (Excel document). The questionnaire about management strategies included questions about; length of the horses' summer pasture (weeks), number of hours outside in the horse paddock per day, number of different surfaces the horses are ridden on, housing (stable or group housing), the manager's experience (years) and education*, the personnel's education*, weight limits and if the riding school had specific strategies to avoid lameness. The questionnaire with horse information included: year of birth, gender, breed, number of riding lessons per week, the total amount of riding lessons in hours per week, type of work during training, number of months at the specific riding school, time since summer pasture, previous lameness and how willing the horse is to work from a scale 1-10. The very subjective questions about strategies for avoiding lameness and the horses' willingness to work, were questions asked out of my interest and not included in the results. Also, when receiving none or very unclear answers about a horse, this was partly excluded. For example, horses without a given age did not participate in the statistical hypothesis testing regarding age and motion asymmetry.

* education could be the equine science program or riding instructor-level (I-III). Secondary education wasn't acknowledged

3.4. Data processing and statistical analysis

Data values received from *Sleip AI* and answers from the questionnaires were written down and organized in Microsoft Excel. Calculations, descriptive statistics, and hypothesis testing was also done in Microsoft Excel. Data was considered/ deemed to be normally distributed based on median and mean values. Therefore, hypothesis testing of different groups was done with a double-sided heteroscedastic t-test, where the level of significance was set at P< 0.05. Grouping for the t-test was based on horses´ age, gender, riding lessons (number and hours), months since the acquisition, previous lameness, summer rest and type of activity, and riding schools grouping based on manager/staff experience. Descriptive statistics and hypothesis testing was done separately for each riding school as well as for all riding schools together.

For the descriptive statistics and hypothesis testing, the horses' so-called total motion asymmetry was used. Each horse's total motion asymmetry was calculated and defined as the mean value from *Sleip AIs* HDmin, HDmax, PDmin, and PDmax added together, from all measurement occasions. In other words, was the focus only on the horse's total size of motion asymmetry, no differences were made between impact or push off lameness or front or hind limb lameness. SD values from *Sleip AI* were not included in any calculations at any point. Further, horses were defined as visible motion asymmetrical when the total motion asymmetry measurements in *Sleip AI* were >0.75.

3.5. Literature

The literature for this master thesis was found through the search engines SLU:s Primo, Google Scholar, PubMed, and ScienceDirect.

4. Results

Four of 14 riding schools contacted (29%), decided to participate in the study, with a total of 76 horses. The results from the motion symmetry measurement, the questionnaires, the descriptive statistics, and hypothesis testing follow below.

4.1. Result of motion asymmetry measurements

The data collected with *Sleip AI* shows us that the total motion asymmetry in all 76 horses ranged from 0.30 to 2.20 (Table 2). In total, 50 of the 76 horses (66%) were measured with relevant (>0.75) total motion asymmetry. Differences in the size of total motion asymmetry between riding schools exist (Figure 1,2).

Additionally, observations of variation in the lameness metrics HDmin, HDmax, PDmin, and PDmax were made between the different measurement occasions of the horses. Some horses remained largely consistent, showing one specific limb and asymmetry, while others differed between occasions. No further investigation or statistics were done concerning this.

Table 2 Descriptive statistics and distribution of total motion asymmetry in all the horses (n = 76) at the four riding schools (RS1-4), as well as their visible (>0.75) total motion asymmetry.

	RS1	RS2	RS3	RS4	Tot
Total motion asymmetry					
n =	16	28	16	16	76
Range	0.50-1.57	0.40-1.80	0.57-1.97	0.30-2.20	0.30-2.20
Median	0.85	0.75	1.07	0.9	0.86
Mean	0.93	0.83	1.13	0.95	0.94
SD	0.30	0.31	0.38	0.52	0.38
Total mtotion asymmetry > 0.75					
Number of horses	11	14	15	10	50
Percentage %	69	50	94	61	66

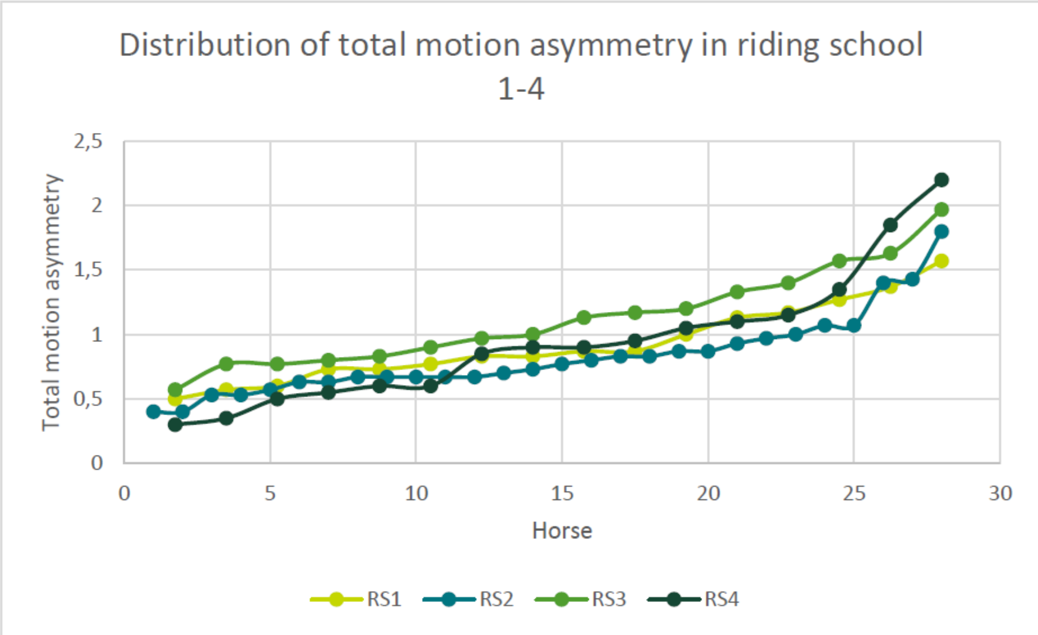

Figure 1 Diagram of all the 76 horses´ total motion asymmetry, shown per horse and sorted from the horse with the lowest to the highest individual value per riding school. Each horse contributes with an individual mean value from all its measurements displayed with a dot.

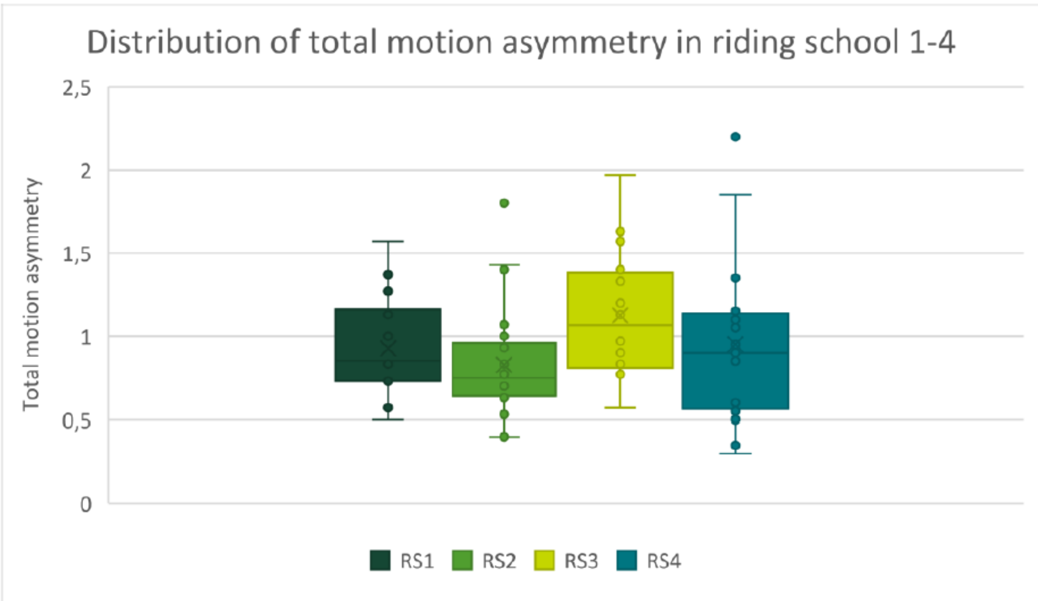

Figure 2 Boxplot of all the horses' (n = 76) total motion asymmetry per riding school (RS1-4), where each horse contributes with an individual value of all its measurements.

4.2. Management factors and motion asymmetry

4.2.1. Management factors

Manager and staff experience

The questionnaire results showed that manager experience ranged between 15 and 40 years in the four riding schools, with a total median and mean of 21.5 respective 25.0 years (Table 3). There was no significant difference (p=0,971) in the horses' total motion asymmetry when comparing RS1 and RS4 (with the least educated staff and manager) to RS2 and RS3 (with the most educated staff and manager).

Table 3 Distribution of the four riding schools'(RS1-4) manager and staff education/experience.

	RS1	RS2	RS3	RS4
Manger expc. (years)	15	21	22	40
Manager educated	Yes	Yes	Yes	No
Staff educated	No	Yes	Yes	No

Summer rest and level of activity

The number of weeks for summer rest was very similar for the four riding schools. Two riding schools (RS1 and RS4) had a summer rest of 4.5 weeks while two had a summer rest of 5.0 weeks (RS3 and RS2). Riding school three (RS3) also wrote, when answering the questionnaire, that there could be some variation in the individual horses' summer rest. Some horses had longer summer rest if they seemed in need of it, while some horses that were sensitive to grass instead had an alternate summer rest with for example light exercise in nature or/and forest. This year, four out of the 16 horses had a summer rest of eight weeks instead of five. The horses with a summer rest of eight weeks were less asymmetrical in their motion measurements (see Figure 3), and there was a significant difference between the two groups (p=0.004).

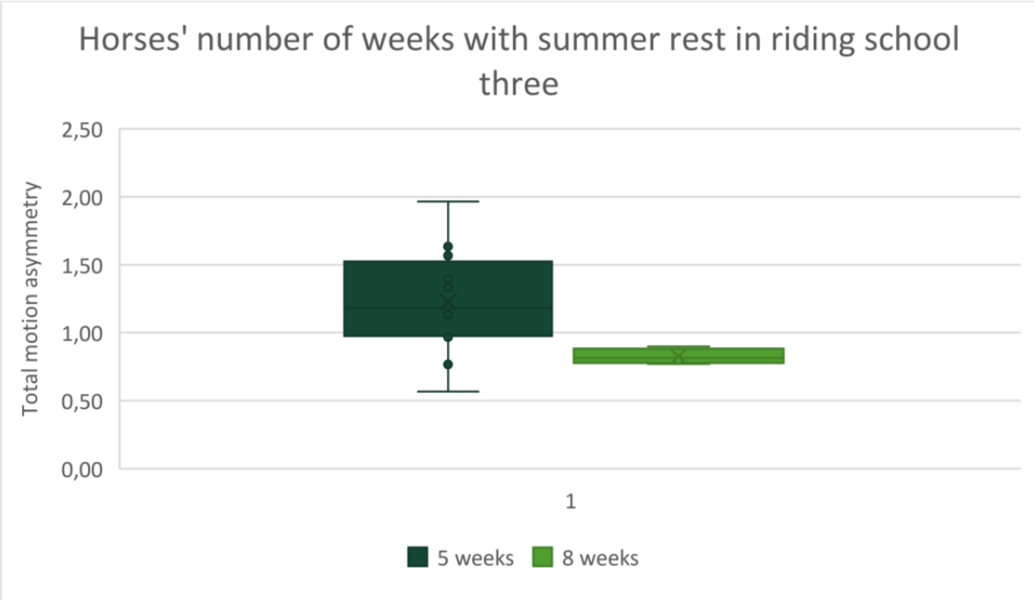

Figure 3 Boxplot of the horses' (n = 16) summer rest in riding school three, divided into two groups, one with five (n=12) and one with eight (n=4) weeks of summer rest (p=0,004).

In terms of the number of riding school lessons per week, there was a high variation, between 2 to 18 per week. The hours of riding school lessons varied between 2 and 16 but note that riding school three (RS3) doesn't contribute with any data. The median respective mean values can be read in Table 5. A significant difference in total motion asymmetry was found (p= 0.0171) between the groups with horses ≤5 and >5 number of lessons per week. A significant difference in total motion asymmetry (p= 0.034) was also found between the groups of horses with <5 and >15 number of lessons per week. In terms of hour of riding school lessons per week (Figure 6), no significant difference in total motion asymmetry (p>0.05) was found.

Table 4 Descriptive statistics and distribution of number and hours of the 75 horses' riding school lessons per week in the four riding schools (RS1-4) and their total value.

	RS1	RS2	RS3	RS4	Tot.
Number of lessons					
Median	11.0	15.0	13.0	17.0	14.0
Mean	10.5	12.9	12.8	14.3	12.6
Lessons (hour)					
Range	4.5-10.5	2.0-16.0	-	2.3-13.5	2.0-16.0
Median	8.3	15	-	12.8	12.0
Mean	7.9	12.9	-	10.8	11.0

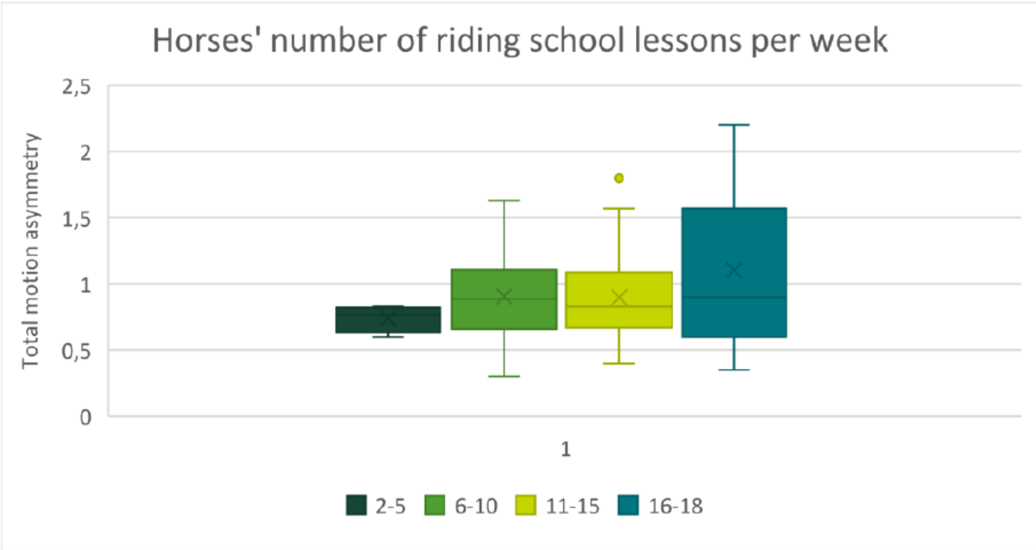

Figure 4 Boxplot of the 75 riding school horses' number of riding school lessons per week, divided into 4 groups: 2-5 (n = 3), 6-10 (n = 14), 11-15 (n = 43) and 16-18 (n = 15) lessons per week.

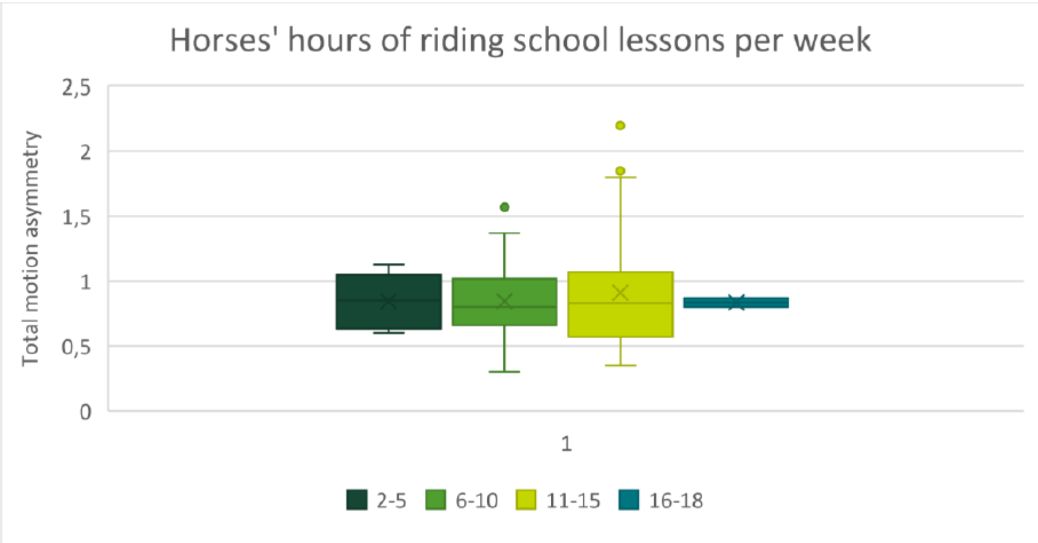

Figure 5 Boxplot of 50 of the riding school horses' hours of riding school lessons per week, in three of the four riding schools (only RS1-2 and RS4 are included). Horses are divided into 4 groups: 2-5 (n = 8), 6-10 (n = 18), 11-15 (n = 31), and 16-18 (n = 2) hours of lessons per week.

Activity type and weight limits for riders

The riding schools' answers concerning the horses' type of activity varied in the level of detail. In riding school one (RS1) all horses did the same type of activity to the same extent, and in riding school two (RS2) the type of activity was described as "easy work" for all horses (Figure 7). No statistical test could be applied to this data. In riding school three (RS3) the type of activity was described in more detail and horses were divided into five groups (Figure 6). Horses in the two groups containing the most (≥15%) jumping activity, were more asymmetrical than horses with less (<15%) jumping activity (p= 0.12). Riding school four has not contributed with data concerning their riding school horses' activity.

Regarding weight limits for riders, riding school two and four (RS1, RS4) both had weight limits while riding school one and three (RS1, RS3) didn´t. With that said, riding schools one and three (RS1, RS3) both mentioned that they were conscious of rider's weights despite no "official" weight limits for riders. No statistical test was applied.

Table 5 Distribution of the horses' (n = 59) type of activity in the riding schools (only including RS1-2, and RS4), and usage of weight limits for riders (RS1-4).

	RS1	RS2	RS3	RS4
Work (%)				
Jumping	18		0-20	-
Dressage	62		50-85	-
Groundwork	20	100 easy work	10-30	-
Gait (%)				
Galopp	15		15	-
Trot	65		65	-
Walk	20		20	-
Weight limits for riders	No	Yes	No	Yes

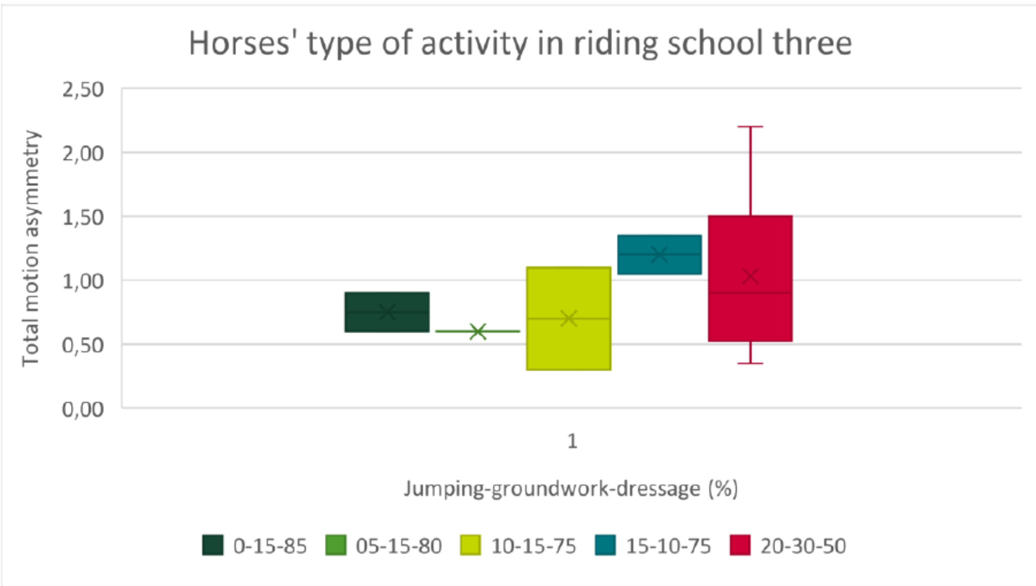

Figure 6 Boxplot of the total motion asymmetry and the activity type (jumping-groundwork-dressage) of the horses (n = 16) in riding school three. Horses were divided into five different groups, with the first group of horses having 0% jumping (J), 15% groundwork (M) and 85% dressage (D) (n=2), the second group having 5% (J), 15% (M) and 80% (D) (n=1), the third group having 10% (J), 15% (M) and 75% (D) (n=2), the forth group having 15% (J), 10% (M) and 75% (D) (n=2) and the fifth group having 20% (J), 30% (M) and 50% (D) (n=9).

Housing, pasture turnout, and riding surface

Results from the questionnaire showed that all riding school horses were kept in box housing and/or conventional tie-stall, no horses were kept in group housing. Horses had pasture turnout somewhere between 4.0 to 7.0 hours, with a mean time of 5.9 hours. The number of different riding surfaces varied between one to four. See Table 8 for further details. No statistical analyses were performed for this data.

Table 6 Distribution of the four riding schools (RS1-4) pasture turnout and riding surfaces.

	RS1	RS2	RS3	RS4
Pasture turnout (hours)	7.0	4.0	6.5	6.0
Riding surface	4	1	3	2
Types of riding surface	Wood chips gravel, grass, asphalt	fiber	fiber sand, forest, wood chips	Gravel, sand

4.2.2. Horse factors

Age

Further answers from the questionnaire included different horse factors, such as age, gender, and breed. The riding school horses' age ranged between five and 27 years but note that six horses were excluded due to the lack of data regarding the horses' age. The total median and mean age was 12 respective 12.3 years (Table 9). Horses in the oldest age group (20-27 years) appeared in the sample to be more asymmetric than the other age groups (Figure 7), but this was not statistically significant (p= 0.378).

Table 7 Descriptive statistics and distribution of the riding school horses' age (n = 70), in all riding schools (RS1-4).

	RS1	RS2	RS3	RS4	Tot
Age (years)					
Range	6-18	6-27	7-25	5-25	5-27
Median	13	10	15.5	11.5	12.3
Mean	12.2	11.1	15.4	11.4	12.3

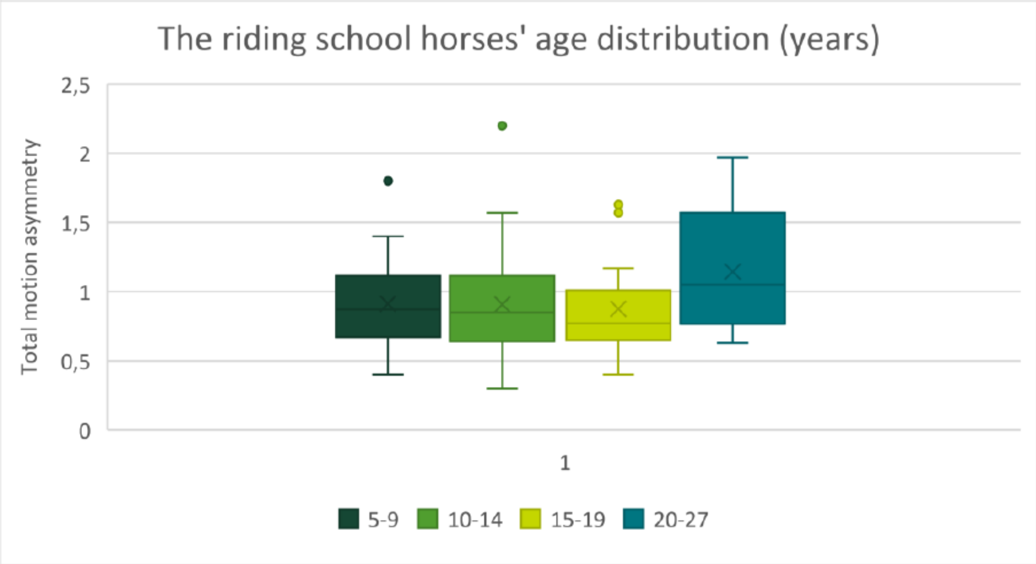

Figure 7 Boxplot of the riding school horses' (n = 74) age, in all four riding schools, divided into four different groups; 5-9 (n = 21), 10-14 (n = 35), 15-19 (n = 13), and 20-27 (n = 5) years old. Four upper outliners are observed in RS1-3, one in group 5-9, one in group 10-14 and two in group 15-19.

Gender and breed

Gender vise, horses were generally equally distributed, and the riding schools' total distribution was 50% mares and 50% geldings (Table 10). There was no significant difference (p=0.83) in the horses' total motion asymmetry when comparing these two groups (Figure 8). As seen in Table 10, horses breed constituted almost only from imports, other Swedish or horses of unknown origin. There was not a significant correlation between total motion asymmetry and the different breed groups (p≥0.05).

Table 8 The riding school horses' distribution in regard to gender (n = 72) and breed (n = 75).

	RS1	RS2	RS3	RS4	Tot
Gender (%)					
Mares	38	57	56	44	50
Geldings	62	43	44	56	50
Breed (%)					
Import	62	57	25	33	44
Other Swedish/unknown	38	39	75	67	55
SWB		4			1

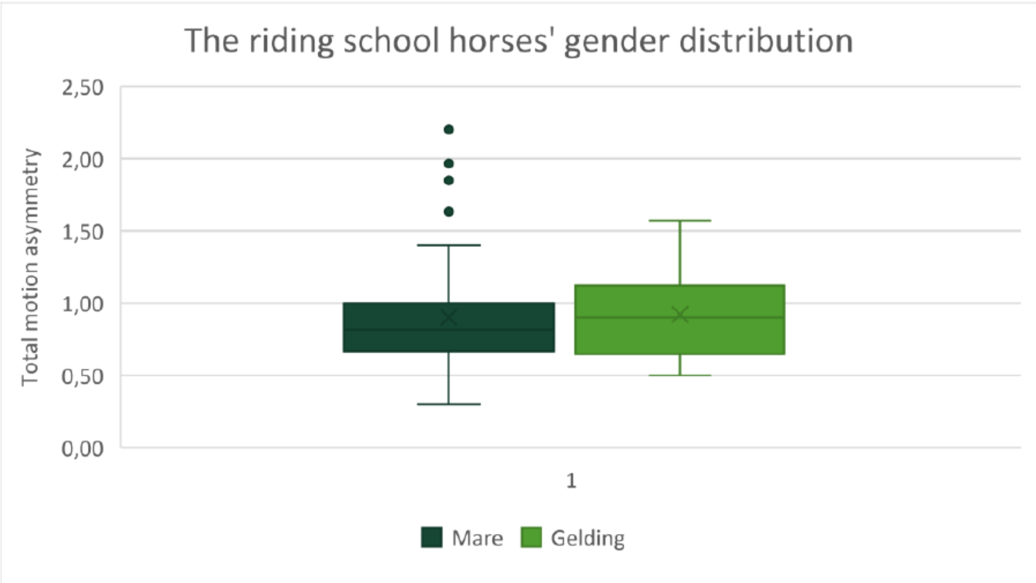

Figure 8 Boxplot of the riding school horses' (n = 72) gender, divided into two groups: mares (n = 36) and geldings (n = 36) (p=0.83).

Time since acquisition and previous lameness

Time since acquisition ranged between 0 and 157 months (13.1 years), and the total median and mean were 58 respective 49 months (Table 11). In Figure 11, horses in the group with the longest time since acquisition (96-157 months) appear more asymmetrical in movement compared to the other groups, but this was non-significant (p=0.283).

Regarding previous lameness, 24 of the 76 (32%) horses had been lame at least once before during their lifetime, with the managers' knowledge. The horses with previous lameness had also larger asymmetrical movement compared to horses with no known lameness history (Figure 10), this was significant (p=0.02). But note that this was not significant when tested separately in the riding schools (RS1-4).

Table 9 Descriptive statistics and distribution of the riding school horses' time since acquisition (n = 75) and previous lameness (n = 76).

	RS1	RS2	RS3	RS4	Tot
Acquisition (months)					
Range	0-157	1 -92	3.6-144	4.8-110	0-157
Median	50	76	54	50	58
Mean	49	49	48	48	49
Previous lameness (%)					
Yes	44	14	44	38	32
No	56	86	56	62	68

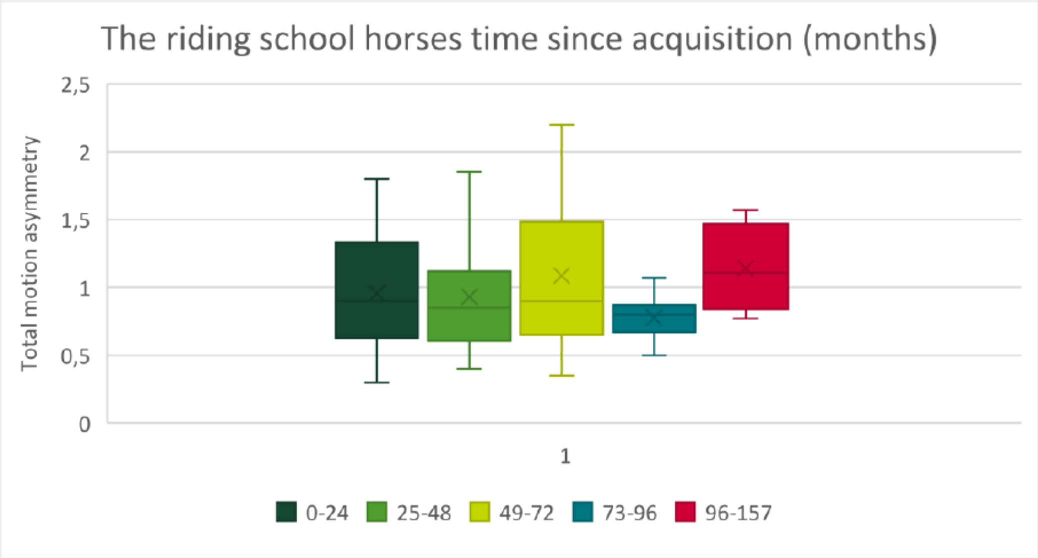

Figure 9 Boxplot of the riding school horses' (n = 75) time since acquisition in months, divided into 5 groups: 0-24 (n = 27), 25-48 (n = 8), 49-72 (n = 13), 73-96 (n = 23) and 96-157 (n = 4) months since acquisition.

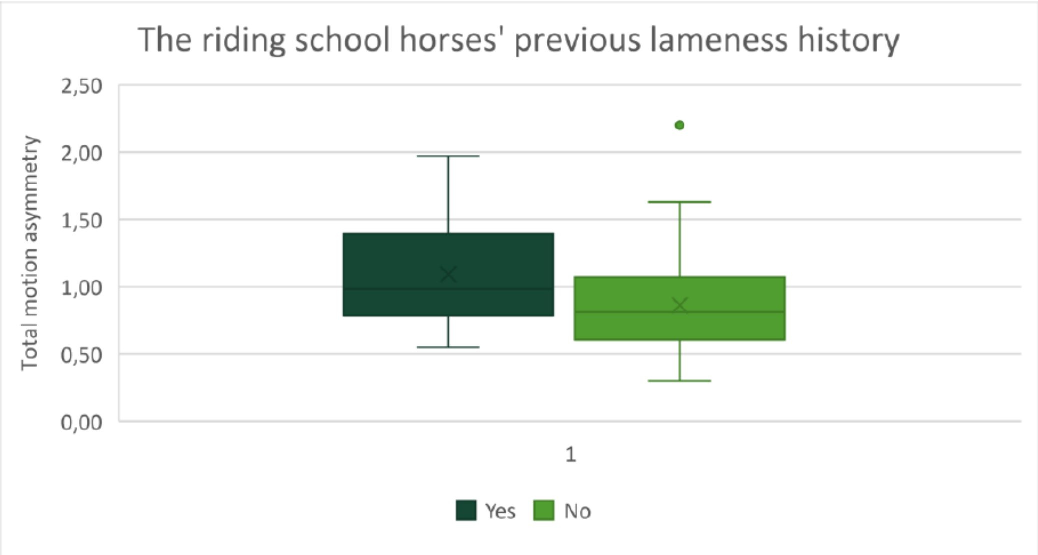

Figure 10 Boxplot of the riding school horses´(n = 76) previous lameness history, divided into two groups: Yes (has been previously lame) (n = 24) and No (hasn't been previously lame with the manager knowing at least) (n = 52).

5. Discussion

This study set out with the aim of describing motion asymmetry, management factors, and horse factors in Swedish riding school horses. Interestingly, a possible association was found between motion asymmetry and management and horse factors in riding school horses.

5.1. Motion asymmetry in the 76 riding school horses

The motion asymmetry measurements in the 76 horses are similar to what we expected and agree with previous literature. Even though all 76 horses were considered sound by the riding school visible total motion asymmetry occurred in 66% of the horses. This is similar to the studies of Rhodin *et al*. (2017) and Kallerud *et al*. (2021), where a large part of the sound horses also was found to be asymmetrical in motion. This further confirms the importance of not equal asymmetrical movement and lameness. The level of relevant total motion asymmetry was set at >0.75 because my supervisor and I concluded this would be a reasonable limit based on previous measurement experiences. With that being said, one could probably have argued for another limit set. For instance, horses with at least >0.5 in motion asymmetry in any limb could have been counted. If another limit would have been used, it could in turn have affected the proportion of horses with considered relevant total motion asymmetry.

Total motion asymmetry varied between the riding schools. This supports the previous discovery by Egenvall *et al.* (2010) that differences in orthopedic health status exist between Swedish riding schools. Also, variation in the lameness metrics HDmin, HDmax, PDmin, and PDmax could be observed between the different measurement occasions, in some horses more than others. This could indicate that some horses' motion asymmetry varies over time, which has also been observed in previous studies motion measuring horses over time. Others might have had underlying problems with a specific limb, which reoccurred as the origin of the asymmetry at several measurements. To investigate the possible reason for this in Swedish riding school horses further studies are needed.

5.2. Management factors causing motion asymmetry?

Generally, all of the data gathered with the questionnaires about the riding school horses' management and horse factors were in agreement with previous literature, which in turn makes our study results more reliable. The results in this study showed a significant difference in total motion asymmetry between horses in groups based on the amount of summer rest (one riding school) number of riding lessons per week and previous lameness (all riding schools included). This supports some of our earlier hypotheses, agrees with the literature, and indicates that these factors could influence riding school horses' motion asymmetry.

Meanwhile, no significant difference in total motion asymmetry was seen between horses in groups which were based on hours of riding school lessons, type of activity, age, gender, breed, and time since acquisition. Some of our earlier hypothesizes, could hence not be confirmed, and it disapproves with the literature. It is however very difficult to prove that there is no difference between the two groups if the sample size is not very large. Negative findings can be due to low study power. Hence, the small sample population and other study limitations could be linked to some of our hypotheses being rejected, which we come back to later.

5.3. Study limitations

This master thesis comes with different types of study limitations and challenges, including the study type, motion asymmetry measurement, the questionnaires, statistical analysis, and human error.

First, it is important to address that a simple sample study can't be trustworthily applied to the whole riding school population in Sweden. Further, this study sample only included a very small sample (n = 4) of the riding school population around Lund, Sweden, because ten of 14 riding schools declined to participate. The small sample increases the risk of clustering, makes it difficult to gather enough information, and, not to mention, difficult to hypothesis test and draw safe conclusions, especially on a riding schools' levels. Additionally, I only visited and measured the riding school horses' on a small number of occasions, giving a limited insight into the riding school horses' motion asymmetry and situation. Further studies should try to improve some of the disadvantages mentioned above. At last, it is also worth mentioning that a study that only focuses on (considered) sound horses might not be optimal to investigate motion asymmetry, and one could consider changing the study population for further similar studies.

Second, improvements for motion asymmetry measurements are discussed. While it was positive that all horses were measured applying the same method every time and generally contributed with a satisfying number of strides, the method could have been improved. To receive more data of the horses' locomotion, horses could for instance been measured on different surfaces (hard, soft), on the lunge, or even ridden. The riding school staff who trotted the horses in-hand, was very few times observed "dragging" the horse, which possibly could affect the HDmax and HDmin values.

Third, the questionnaires, which were thought through well, still came with limitations. Not only did some riding schools not answer all of the questions, but the managers also had difficulties being completely sure about their answers. For example, the questions about a horse's previous lameness can be difficult to answer correctly, if the manager hasn't been part of all the horses' past medical history. Further, it would have been more beneficial with clearer questions regarding the type of activity and breed (differing between horses and ponies), as well as including more relevant questions of possible factors (horseshoeing or other breaks than summer rest) having an impact on motion asymmetry. Additionally, since unhealthy and temperamental horses were excluded from the study, it could have been of interest to add a question about the number of horses excluded and the reasons why.

5.4. Conclusion

In conclusion, the results indicate that riding school horses show different degrees of objectively measured motion asymmetry based on management and horse factors. Especially factors including the amount of summer rest, number of riding lessons per week, and previous lameness affected the motion asymmetry. Further studies are needed in this field of study to draw more conclusions. These should include larger study material and follow the horses' motion symmetry over a longer period of time. Also, more management and horse factors that possibly can affect the horses' motion symmetry should be included.

References

Arkell, M., Archer, R.M., Guitian, F.J. & May, S.A. (2006). Evidence of bias affecting the interpretation of the results of local anaesthetic nerve blocks when assessing lameness in horses. *Veterinary Record*, 159 (11), 346–348. https://doi.org/10.1136/vr.159.11.346

Axelsson, M., Björnsdottir, S., Eksell, P., Häggström, J., Sigurdsson, H. & Carlsten, J. (2001). Risk factors associated with hindlimb lameness and degenerative joint disease in the distal tarsus of Icelandic horses. *Equine Veterinary Journal*, 33 (1), 84–90. https://doi.org/10.2746/042516401776767502

Baxter, G.M., Stashak, T.S. & Keegan, K.G. (2020). Examination for lameness. *Adams and Stashak's Lameness in Horses*. John Wiley & Sons, Ltd, 67–188. https://doi.org/10.1002/9781119276715.ch2

Bell, R.A., Nielsen, B.D., Waite, K., Rosenstein, D. & Orth, M. (2001). Daily access to pasture turnout prevents loss of mineral in the third metacarpus of Arabian weanlings. *Journal of Animal Science*, 79 (5), 1142–1150. https://doi.org/10.2527/2001.7951142x

Bosch, S., Serra Bragança, F., Marin-Perianu, M., Marin-Perianu, R., van der Zwaag, B.J., Voskamp, J., Back, W., van Weeren, R. & Havinga, P. (2018). EquiMoves: A wireless networked inertial measurement system for objective examination of horse gait. *Sensors (Basel, Switzerland)*, 18 (3), 850. https://doi.org/10.3390/s18030850

Buchner, H.H., Savelberg, H.H., Schamhardt, H.C. & Barneveld, A. (1996). Head and trunk movement adaptations in horses with experimentally induced fore- or hindlimb lameness. *Equine Veterinary Journal*, 28 (1), 71–76. https://doi.org/10.1111/j.2042-3306.1996.tb01592.x

Clayton, H.M., Dyson, S., Harris, P. & Bondi, A. (2015). Horses, saddles and riders: Applying the science. *Equine Veterinary Education*, 27 (9), 447–452. https://doi.org/10.1111/eve.12407

Donnell, J.R., Frisbie, D.D., King, M.R., Goodrich, L.R. & Haussler, K.K. (2015). Comparison of subjective lameness evaluation, force platforms and an inertial-sensor system to identify mild lameness in an equine osteoarthritis model. *The Veterinary Journal*, 206 (2), 136–142. https://doi.org/10.1016/j.tvjl.2015.08.004

Dyson, S., Ellis, A.D., Mackechnie-Guire, R., Douglas, J., Bondi, A. & Harris, P. (2020). The influence of rider:horse bodyweight ratio and rider-horse-saddle fit on equine gait and behaviour: A pilot study. *Equine Veterinary Education*, 32 (10), 527–539. https://doi.org/10.1111/eve.13085

Egenvall, A., Bonnett, B.N., Olson, P., Penell, J. & Emanuelson, U. (2006). Association between costly veterinary-care events and 5-year survival of Swedish insured warmblooded riding horses. *Preventive Veterinary Medicine*, 77 (1), 122–136. https://doi.org/10.1016/j.prevetmed.2006.07.002

Egenvall, A., Lönnell, C., Johnston, C. & Roepstorff, L. (2010). Orthopaedic health status of horses from 8 riding schools - a pilot study. *Acta Veterinaria Scandinavica*, 52 (1), 50. https://doi.org/10.1186/1751-0147-52-50

Egenvall, A., Lönnell, C. & Roepstorff, L. (2009). Analysis of morbidity and mortality data in riding school horses, with special regard to locomotor problems. *Preventive Veterinary Medicine*, 88 (3), 193–204. https://doi.org/10.1016/j.prevetmed.2008.10.004

Egenvall, A., Penell, J.C., Bonnett, B.N., Olson, P. & Pringle, J. (2005). Morbidity of Swedish horses insured for veterinary care between 1997 and 2000: Variations with age, sex, breed and location. *Veterinary Record*, 157 (15), 436–443. https://doi.org/10.1136/vr.157.15.436

Georgopoulos, S.P. & Parkin, T.D.H. (2016). Risk factors associated with fatal injuries in Thoroughbred racehorses competing in flat racing in the United States and Canada. *Journal of the American Veterinary Medical Association*, 249 (8), 931–939. https://doi.org/10.2460/javma.249.8.931

Graham-Thiers, P.M. & Bowen, L.K. (2013). Improved ability to maintain fitness in horses during large pasture turnout. *Journal of Equine Veterinary Science*, 33 (8), 581–585. https://doi.org/10.1016/j.jevs.2012.09.001

Hardeman, A.M., Serra Bragança, F.M., Swagemakers, J.H., van Weeren, P.R. & Roepstorff, L. (2019). Variation in gait parameters used for objective lameness assessment in sound horses at the trot on the straight line and the lunge. *Equine Veterinary Journal*, 51 (6), 831–839. https://doi.org/10.1111/evj.13075

Hockenhull, J. & Creighton, E. (2015). The day-to-day management of UK leisure horses and the prevalence of owner-reported stable-related and handling behaviour problems. *Animal Welfare*, 24 (1), 29–36. https://doi.org/10.7120/09627286.24.1.029

Kallerud, A.S., Fjordbakk, C.T., Hendrickson, E.H.S., Persson-Sjodin, E., Hammarberg, M., Rhodin, M. & Hernlund, E. (2021). Objectively measured movement asymmetry in yearling Standardbred trotters. *Equine Veterinary Journal*, 53 (3), 590–599. https://doi.org/10.1111/evj.13302

Kaneene, J.B., Ross, W.A. & Miller, RA. (1997). The Michigan equine monitoring system. II. Frequencies and impact of selected health problems. *Preventive Veterinary Medicine*, 29 (4), 277-292. https://doi.org/10.1016/S0167-5877(96)01080-X

Kaufman, K. & An, K. (2017). Chapter 6 - Biomechanics. In: Firestein, G.S., Budd, R.C., Gabriel, S.E., McInnes, I.B., & O'Dell, J.R. (eds.) *Kelley and Firestein's Textbook of Rheumatology* (Tenth Edition). Elsevier, 78–89. https://doi.org/10.1016/B978-0-323-31696-5.00006-1

Keegan, K.G. (2005). Head movement pattern in horses with forelimb and hindlimb lameness. *Proceedings of the 51st Annual Convention of the American Association of Equine Practitioners*, Seattle, Washington, USA, 3-7 December, 2005, 114–120

Keegan, K.G., Dent, E.V., Wilson, D.A., Janicek, J., Kramer, J., Lacarrubba, A., Walsh, D.M., Cassells, M.W., Esther, T.M., Schiltz, P., Frees, K.E., Wilhite, C.L., Clark, J.M., Pollitt, C.C., Shaw, R. & Norris, T. (2010). Repeatability of subjective evaluation of lameness in horses. *Equine Veterinary Journal*, 42 (2), 92–97. https://doi.org/10.2746/042516409X479568

Kielén, M., Olsson, Y., Nordgren, M., & North, M (2018). *Hästhållningen i Sverige 2016*. (2018:12). Swedish Board of Agriculture. [2021-10-07]

Kramer, J. & Keegan, K.G. (2014). 12 - Kinematics of lameness. In: Hinchcliff, K.W., Kaneps, A.J., & Geor, R.J. (eds.) *Equine Sports Medicine and Surgery* (Second Edition). W.B. Saunders, 223–238. https://doi.org/10.1016/B978-0-7020-4771-8.00012-0

Lönnell, C., Roepstorff, L. & Egenvall, A. (2012). Variation in equine management factors between riding schools with high vs. low insurance claims for orthopaedic injury: A field study. *The Veterinary Journal*, 193 (1), 109–113. https://doi.org/10.1016/j.tvjl.2011.11.003

MacKinnon, M.C., Bonder, D., Boston, R.C. & Ross, M.W. (2015). Analysis of stress fractures associated with lameness in Thoroughbred flat racehorses training on different track surfaces undergoing nuclear scintigraphic examination. *Equine Veterinary Journal*, 47 (3), 296–301. https://doi.org/10.1111/evj.12285

McCracken, M.J., Kramer, J., Keegan, K.G., Lopes, M., Wilson, D.A., Reed, S.K., LaCarrubba, A. & Rasch, M. (2012). Comparison of an inertial sensor system of lameness quantification with subjective lameness evaluation. *Equine Veterinary Journal*, 44 (6), 652–656. https://doi.org/10.1111/j.2042-3306.2012.00571.x

Murray, R.C., Walters, J., Snart, H., Dyson, S. & Parkin, T. (2010). How do features of dressage arenas influence training surface properties which are potentially associated with lameness? *The Veterinary Journal*, 186 (2), 172–179. https://doi.org/10.1016/j.tvjl.2010.04.026

Nagy, A., Murray, J.K. & Dyson, S.J. (2014). Descriptive epidemiology and risk factors for eliminations from Fédération Equestre Internationale endurance rides due to lameness and metabolic reasons (2008–2011). *Equine Veterinary Journal*, 46 (1), 38–44. https://doi.org/10.1111/evj.12069

Penell, J.C., Egenvall, A., Bonnett, B.N., Olson, P. & Pringle, J. (2005). Specific causes of morbidity among Swedish horses insured for veterinary care between 1997 and 2000. *Veterinary Record*, 157 (16), 470–477. https://doi.org/10.1136/vr.157.16.470

Rhodin, M., Egenvall, A., Haubro Andersen, P. & Pfau, T. (2017). Head and pelvic movement asymmetries at trot in riding horses in training and perceived as free from lameness by the owner. *PLoS One*, 12(4):e0176253. https://doi: 10.1371/journal.pone.0176253.

Ross, M.W. (2011a). Chapter 2 - Lameness in horses: Basic facts before starting. In: Ross, M.W. & Dyson, S.J. (eds.) *Diagnosis and Management of Lameness in the Horse* (Second Edition). Saint Louis: W.B. Saunders, 3–8. https://doi.org/10.1016/B978-1-4160-6069-7.00002-X

Ross, M.W. (2011b). Chapter 3 - Anamnesis (History). In: Ross, M.W. & Dyson, S.J. (eds.) *Diagnosis and Management of Lameness in the Horse* (Second Edition). Saint Louis: W.B. Saunders, 3–8. https://doi.org/10.1016/B978-1-4160-6069-7.00002-X

Sarrafchi, A. & Blokhuis, H.J. (2013). Equine stereotypic behaviors: Causation, occurrence, and prevention. *Journal of Veterinary Behavior*, 8 (5), 386–394. https://doi.org/10.1016/j.jveb.2013.04.068

Serra Bragança, F.M., Rhodin, M. & van Weeren, P.R. (2018). On the brink of daily clinical application of objective gait analysis: What evidence do we have so far from studies using an induced lameness model? *Veterinary Journal (London, England: 1997)*, 234, 11–23. https://doi.org/10.1016/j.tvjl.2018.01.006

Starke, S.D. & Oosterlinck, M. (2019). Reliability of equine visual lameness classification as a function of expertise, lameness severity and rater confidence. *The Veterinary Record*, 184 (2), 63. https://doi.org/10.1136/vr.105058

Swedish Equestrian Federation (2019). *Statistik*. https://www.ridsport.se/Omoss/Statistik [2021-09-21]

Thal, D. (2016). *Understanding Lameness.* American Association of Equine Practitioners. https://aaep.org/horsehealth/understanding-lameness [2021-09-21]

Uhlir, C., Licka, T., Kübber, P., Peham, C., Scheidl, M. & Girtler, D. (1997). Compensatory movements of horses with a stance phase lameness. *Equine Veterinary Journal.* Supplement, (23), 102–105. https://doi.org/10.1111/j.2042-3306.1997.tb05065.x

Uprichard, K.L., Boden, L.A. & Marshall, J.F. (2014). An online survey to characterise spending patterns of horse owners and to quantify the impact of equine lameness on a pleasure horse population. *Equine Veterinary Journal*, 46 (S47), 4–4. https://doi.org/10.1111/evj.12323_7

USDA Animal Plant Health Inspections Service. (2001). *National Economic Cost of Equine Lameness, Colic, and Equine Protozoal Myeloencephalitis (EPM) in the United States.* Virginia Cooperative Extension Newsletter Archive. 2001. https://www.aphis.usda.gov/animal_health/nahms/equine/downloads/equine98/Equine98_is_EconCost.pdf [2021-09-20]

van Weeren, P.R., Pfau, T., Rhodin, M., Roepstorff, L., Serra Bragança, F. & Weishaupt, M.A. (2017). Do we have to redefine lameness in the era of quantitative gait analysis? *Equine Veterinary Journal*, 49 (5), 567–569. https://doi.org/10.1111/evj.12715

Yngvesson, J., Rey Torres, J.C., Lindholm, J., Pättiniemi, A., Andersson, P. & Sassner, H. (2019). Health and body conditions of riding school horses housed in groups or kept in conventional tie-stall/box housing. *Animals : an Open Access Journal from MDPI*, 9 (3), 73. https://doi.org/10.3390/ani9030073

Acknowledgements

I would like to express my sincere gratitude to all those who have inspired, helped, and supported me through the process of this master's thesis.

Special thanks to my supervisor Elin Hernlund, who has done incredible work to inspire, teach and support me throughout the whole process. Thank you for your positive energy when facing difficulties and that you always were available.

I would also like to thank Agneta Egenvall for all the support and wise words regarding the statistical part of the master's thesis, and Selma Claar for helping me improve my questionnaires.

Finally, I would of course like to express my gratitude to all riding schools that I came to visit. This master's thesis wouldn't have been possible without you. Thank you for your time and effort, I appreciate it a lot.

Popular science summary

In Sweden as well as globally lameness or locomotor problems in horses is an important health issue. Lameness in horses is the most common sign of disease, the most common reason for euthanasia, and comes with welfare issues and economic loss. One of many ways to recognize lameness in a horse is by having a veterinarian evaluate its locomotion, where a lame horse commonly occurs asymmetrically. The horses' locomotion can be evaluated subjectively by a veterinarian watching the horses' motion, or, for more reliable results, be measured objectively with different technological tools. But it is important to not equal lameness to motion asymmetry. Lameness can cause motion asymmetry, but, as many researchers stress, motion asymmetry doesn´t have to mean the horse is lame. Horses that are motion asymmetrical can still be sound.

Riding school horses represent an important part of the Swedish horse industry, with 10 700 horses being active in Swedish riding schools in 2019. Previous studies have found differences in horses' orthopedic health status between riding schools, which were suggested to be associated with the riding schools' management and individual horse factors. For example, a management factor could be the horses' number of riding school lessons per week and a horse factor could be the horses' age or breed. This master´s thesis aimed to further describe riding school horses' orthopedic health status by measuring horses' locomotion, management factors, and horse factors in Swedish riding school horses.

Four of the 14 contacted riding schools participated in the current study, leaving us with a total of 76 horses. Management and horse factors were investigated by questionnaires answered by the riding school managers. Locomotion was measured with a new smartphone app called Sleip AI, which recognizes the horses' locomotion with computer vision and artificial intelligence. The horses were recorded with the smartphone trotting in-hand in a straight line on hard ground 30 meters two times back and forth (approximately 120 meters in total). Each horse was measured on two or three different occasions, with 7-8 days between. Measurements values were extracted from each horse's measurement occasion. A representation of the horse's total amount of motion asymmetry was calculated and then a mean value of the horse's total motion asymmetry was calculated. The mean total asymmetry was used to describe the horses' motion symmetry, in the statistics and for hypothesis testing. In our study, a horse was defined as having a relevant total motion asymmetry when the value was >0.75. This value was based on clinical experience. Hypothesis testing was done by grouping horses based on age, gender, number and hours of riding lessons per week, months since the acquisition, previous lameness, summer rest, and type of activity, and by using a so-called double-sided t-test, to investigate differences in total motion asymmetry between groups. The t-tests' level of significance was set to $p < 0.05$.

Results showed that in the four riding schools the total motion asymmetry value ranged from 0.30 to 2.20. In total, 50 of the 76 horses (66%) were considered to have a relevant (>0.75) motion asymmetry. A significant difference in total motion asymmetry was found between horses in groups based on the amount of summer rest in one riding school (p=0.004), the number of riding lessons per week (p=0.017 and p=0.034), and previous lameness (p=0.02) in all riding schools together. This could indicate that these factors influence horses' motion symmetry. No significant difference in total motion asymmetry was seen between horses in groups which were based on hours of riding school lessons, type of activity, age, gender, breed, and time since acquisition. Which in turn could indicate that these factors do not influence horses' locomotion. But by looking at our data and diagrams, (non-significant) differences in total motion asymmetry within the studied horse sample were also seen between subgroups based on the type of activity (one riding school), age, and time since acquisition. Which makes it possible that these factors could play a role anyway. Further, variation in the measurements values was observed (but wasn't further investigated) between the measurement occasions. Some horses were observed to repeatedly show asymmetry from the same limb, while in other horses the origin of the asymmetry differed between the measurement occasions.

In conclusion, results and findings from this study indicate that differences in riding school horses' motion asymmetry can be associated with management and horse factors. The results support that specific attention should be given to the amount of summer rest, number of riding lessons per week, and previous lameness. but likely other management and horse factors can be of importance too. Our results agree with previous literature concerning riding school horses' orthopedic health status in Sweden. Additional studies are needed to draw robust conclusions. Further studies should include more riding schools and horses and follow the horses' locomotion over a longer period of time. Also, more management and horse factors that possibly can affect the horses' locomotion should be included.

Appendix 1

SLU
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Institutionen för anatomi, fysiologi och biokemi

Djurägarmedgivande

Jag godkänner att data som samlas in i samband med besöket/besöken samt data som samlas in via appen *Sleip AI* kan användas till forskning och utveckling.

Jag har läst informationsbladet och är införstådd i vilken data som avses och vilken typ av projekt den kan komma att användas i.

Hantering av personuppgifter

I informationsbladet har jag fått information om var jag kan läsa mer om hantering av personuppgifter inom detta projekt (https://www.slu.se/langtdjurliv).

☐ Kryssa i rutan om du INTE godkänner att videofilm från försöket används vid forskningspresentationer eller i undervisningssyfte.

Jag har tagit del av och förstått ovanstående information och godkänner ridskolan

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Ort _____________________ den 2021

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Appendix 2

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Institutionen för anatomi, fysiologi och biokemi

Samtyckeblankett: Personuppgiftsbehandling i studentarbeten

När du medverkar i examensarbetet om rörelseasymmetri hos ridskolehästar innebär det att SLU behandlar dina personuppgifter. Att ge SLU ditt samtycke är helt frivilligt, men utan behandlingen av dina personuppgifter kan inte forskningen genomföras. Denna blankett syftar till att ge dig all information som behövs för att du ska kunna ta ställning till om du vill ge ditt samtycke till att SLU hanterar dina personuppgifter eller inte.

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Vi samlar in följande uppgifter om dig: kontaktuppgifter, uppgifter om ridskola och hästar. Dessa kommer sparas i maximalt 1 år och efter avslutat examensarbete raderas. I examensarbetet kommer medverkande ridskolor och hästar att vara helt anonyma.

Ändamålet med behandlingen av dina personuppgifter är att SLUs student ska kunna genomföra sitt examensarbete enligt korrekt vetenskaplig metod och bidra till forskning på rörelseasymmetri hos ridskolehästar.

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☐ Jag samtycker till att SLU behandlar personuppgifter om mig på det sätt som förklaras i denna text, inklusive känsliga uppgifter om jag lämnar sådana.

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