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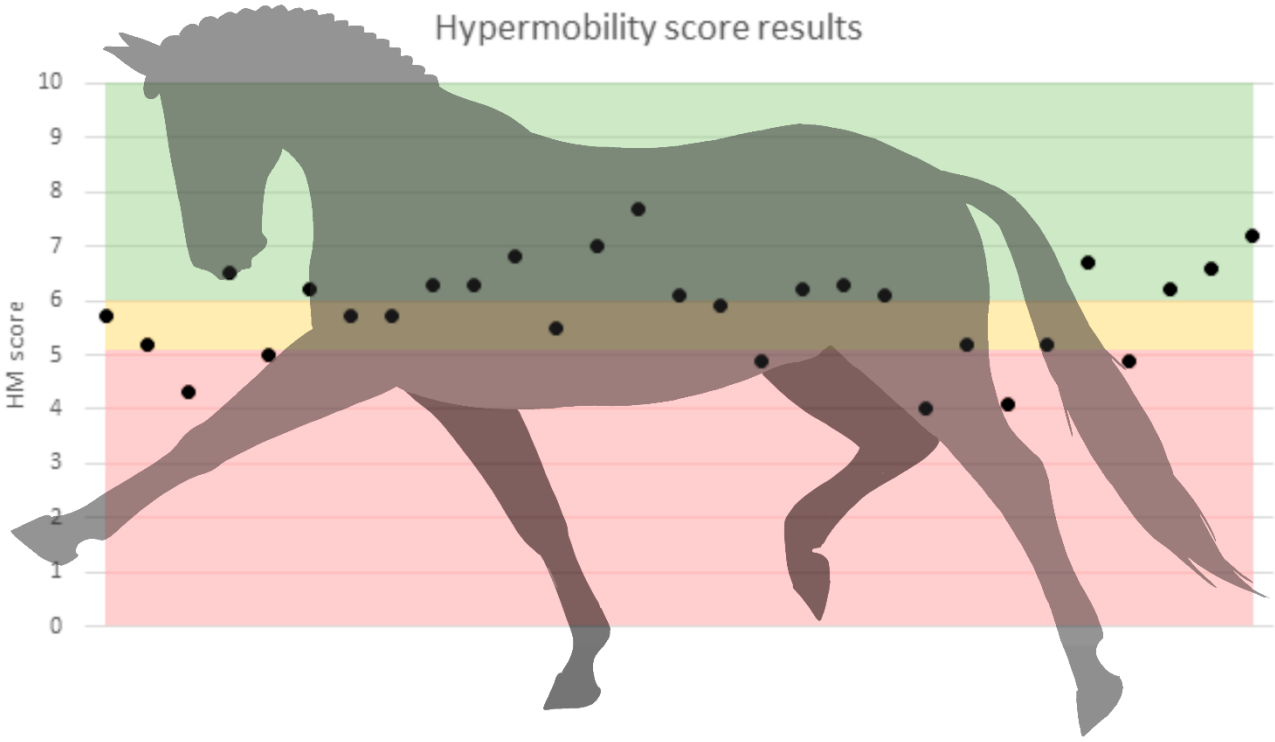

Master thesis

45 ECTS points

Equine Hypermobility

- **Using Acoustic Myography to assess Hypermobility in horses**

Supervisor: Adrian Paul Harrison

Submitted on: March 29, 2023

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Supervisor:	Adrian Paul Harrison
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Malene Leth Flyttov Jørgensen

How it started…

It all started when I heard an equine physiotherapist talking about modern horses being more fragile because they were born with flashy gaits and no strength, probably because of hypermobility. Studying animal science where welfare, especially prevention of decreased welfare like injuries and stress, is in focus, I found the topic of hypermobility very interesting. As there is hardly any data on the subject, I thought that this was an area where I would be able to contribute. In the summer of 2022, I made a preliminary study on hypermobility, which this master thesis is now based on.

Thanks to…

My family for being patient and backing me up when needed. My supervisor Adrian Paul Harrison for advisements and making acoustic myography available. Anna Hvid for spell and grammar proofing. And all the horse owners who let their horses be measured for this master thesis, contributing with valuable data making this study possible.

Abstract

Background: This master thesis is building further on the study done by Jørgensen (2022), aiming to create a suitable objective tool to measure hypermobility in horses. By using acoustic myography (AMG), muscle activity was measured on the *ulnaris lateralis*, *extensor carpi radialis*, *gluteus medius* and *biceps femoris* in the moving phases, backing up (backing up) and walking forward (walk). Five horses participated in the preliminary trial where all four muscle groups were measured on the left side. The front limb muscles were also measured on the right side. In the full trial where the left side front limb muscles were measured, 29 horses participated. The data from the measurements were analyzed and compared to assess signs of hypermobility.

Results: Using the ST mean values (S being spatial summations and T being temporal summation from the AMG measurements) an overall HM score was created, and the horses were assessed as being non-hypermobile (55%, n=16), borderline (24%, n=7) and hypermobile (21%, n=6). The results showed an individual preference of muscle groups used in moving phases between the horses, and a difference in muscle activity (ST mean and HM score) from horse to horse, giving indications of difference between hypermobility and possible injuries.

Conclusion: It is possible that AMG can be used to measure hypermobility in horses, as some of the test horses had a decreased HM score, which may indicate that hypermobility can be assessed through muscle activity in specific muscle groups. By creating an HM score using specific muscle groups, AMG can be used as a diagnostic tool.

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1. Introduction

Horses, *Equus ferus caballus*, are used in many ways, such as athletes in competitive sports, companions, hobby animals and therapy. The horse industry is big and expensive, with top horses sold for millions. Keeping horses healthy is therefore a priority for the many people involved in the industry.

Hypermobility could pose a problem for some horses' welfare, health, and ability to be ridden. Through personal communication with several equine physiotherapists, it has been clear that they share a concern, as they see more and more horses being hypermobile, and having injuries or problems in riding. In the report by Jørgensen (2022), four physiotherapists assessed 33% of their patients as being 'whole body' hypermobile, which was assessed to be the equivalent to naturally occuring hypermobility. However, hypermobility is not well documented in equine medicine, and a proper objective assessment method needs to be established to investigate the true extent of the problems related to hypermobility.

This master thesis is based on data from the PUK (project outside the corse scope) study with 40 horses done by Jørgensen (2022), and is considered to be a extension of the study, improving upon the method of measuring hypermobility in horses using acoustic myography (AMG).

1.1 Aim and hypotheses

The aim of this master thesis is to investigate if and how acoustic myography (AMG) can be used to measure hypermobility in horses, by testing different muscles on a group of horses, with presumably both hypermobile and non-hypermobile horses represented. The study also aims at creating a diagnostic tool that is easy and reliable to use in research purposes.

This study will build on the work done previously by Jørgensen (2022), acknowledging that hypermobility can be naturally occuring in a population either through evolution or breeding.

Hypotheses

I. AMG can be used to assess hypermobility in horses through the spatial and temporal summations of the muscles' activity.

II. Hypermobility can be determined through measurements combining the spatial and temporal summations of muscle activities in different muscle groups.
III. AMG can be used as a diagnostic tool for use in the future.

2. Background

Hypermobility in horses, and in humans, is often only looked at when it is a symptom of a disease or disorder. Naturally occurring hypermobility is therefore not well documented or investigated, and an assessment method that is objective and repetitive needs to be found. In this master thesis, hypermobility is defined as naturally occurring through a change in the DNA, which affects the fibrous protein genes encoding collagen, elastin and fibrilin (Grahame, 1999). This means that connective tissue in the whole body is affected by the change, making hypermobility both genetically hereditary and separate from local or forced hypermobility that occurs through repetitive movement of a specific joint.

Some diseases have hypermobility as a symptom, such as Ehlers-Danlos syndrome (in humans) which is usually hereditary and is autosomal dominant but can also be caused by new mutations in the collagen encoding genes. In horses, a similar disease has been suggested to be an autosomal recessive mutation, but an autosomal dominant inheritance has also fit the pattern (Hardy, et al., 1988). This differs from naturally occurring hypermobility that is assumed to be caused by evolution or favoritism of specific traits, taking generations to occur. However, Ehlers-Danlos syndrome is well studied, and may contribute to a better understanding of hypermobility.

Ehlers-Danlos syndrome in humans has 13 variations and affects 20 different genes encoding collagen primary structures and collagen processing. Differentiating naturally occurring hypermobility from hypermobility due to Ehlers-Danlos syndrome may be difficult, although naturally occurring hypermobility seems to have lesser pathological effects, and most humans live unaffected lives. Equine models of Ehlers-Danlos syndrome such as hereditary equine regional dermal asthenia (HERDA) have been studied (McElroy, et al.), but are not considered common. HERDA is mostly seen in American horse breeds like the quarter horse, the paint horse, and the appaloosa, where a test can determine if a horse has the gene. Similar diseases have also been found in dogs, cats, and mink where a collagen packing defect seems to dominate the connective tissue throughout the animal's body (Hardy, et al., 1988). Whether or not hypermobility is caused by a

disease is difficult to conclude, but it can be assumed that hypermobility in most Danish horses may be naturally occurring, because Ehlers-Danlos syndrome is rare in humans, 1 in 5000 in humans (Pyeritz, 2000) (Søborg, Leganger, Mortensen, Burcharth, & Rosenberg, 2017), and HERDA primarily exists in American quarter horses (2.5 to 3.8 %) (Schultz N. , 2021).

Not depending on a disease to develop, naturally occurring hypermobility is something an individual is born with and is dependent on a change in the collagen throughout the body impacting connective tissues, like ligaments, making them looser and decreasing their capability to stabilize joints. This means that the range of motion in the joints is wider than in non-hypermobile individuals. The risk of dislocation is higher as well as the risk of damage to the muscles, as they can be overstretched. Other documented problems (in human medicine) that can be related to either hypermobility or a change in collagen are fatigue, pain and stiffness in joints and muscles, back and neck pain, night pains, poor coordination, recurrent injuries in the soft tissue, digestive problems and thin or stretchy skin (MSK expert panel, 2022).

Another issue hypermobile horses could be exposed to is decreased proprioception. Proprioception is the sensation of body position and movement that is individual and often not a conscious perception (Tuthill & Azim, 2018). Joint proprioception has, in human medicine, been documented to be decreased in musculoskeletal conditions like osteoarthritis and ligament injuries, as well as in people with increased joint hypermobility, like Ehlers-Danlos. A loss in proprioception in the lower limb was also found in people with benign joint hypermobility (Smith, et al., 2013). A study by Hall, Ferrel, Sturrock, Hamblen, & Baxendale (1995) suggests that people with hypermobility syndrome have decreased proprioceptive feedback, which could lead to unsound limb positions.

It is therefore possible that naturally occurring hypermobility can result in a decrease in proprioception as well, although this has not been documented in humans or horses. A decrease in proprioception could result in an increase in injuries and poor results in competitions where body awareness is important such as dressage and jumping.

2.1 Hypermobility in horses

Equine physiotherapists are assessing more horses as being hypermobile over the years (personal contact) and have assessed that 33% of their equine patients were ‘whole body’ hypermobile, and 85% of them had problems with riding like stiffness, problem behavior and injuries, compared to their non-hypermobile patients with 73% (Jørgensen, 2022). Horses assessed

as being ‘whole body’ hypermobile therefore seem to have an increased risk of injuries and problem behavior caused by pain or stiffness in their bodies.

With the pressure of peaking at a specific time when competing, the knowledge of the impact hypermobility has on the horse, could therefore be of great importance. Dressage horses, especially warmbloods, and horses competing in Icelandic horse riding competitions were at risk of being hypermobile and having physiological or behavioral problems according to the data collected by the physiotherapists in the study by Jørgensen (2022).

Because of the problems related to hypermobility seen in humans, hypermobile horses could have different needs to maintain a satisfying welfare while competing at higher levels. Shorter training sessions to prevent fatigue, the need for more strengthening work, different holding facilities that meet the need of free movement to prevent a loss in bone density, and nutrition that benefits the digestive system. All of these may need to be considered to insure the welfare of the hypermobile horse, and to make it peak when needed in competitions.

Equine sports is an expensive industry, making it advantageous for riders, stable owners, sponsors and trainers to find out more about hypermobility in horses, so that the true impact on the horse as well as related problems can be investigated and documented.

How common hypermobility is in horses is, however, unclear. In the human population, hypermobility seems to have a prevalence of 10-20% in a general population and is more common in children and women (Hakim & Grahame, 2003). Similar findings were found by the physiotherapists participating in the study by Jørgensen (2022), as the data collected by the therapists showed that younger horses had a higher risk of being hypermobile, giving the impression that it is something that can be outgrown in some horses.

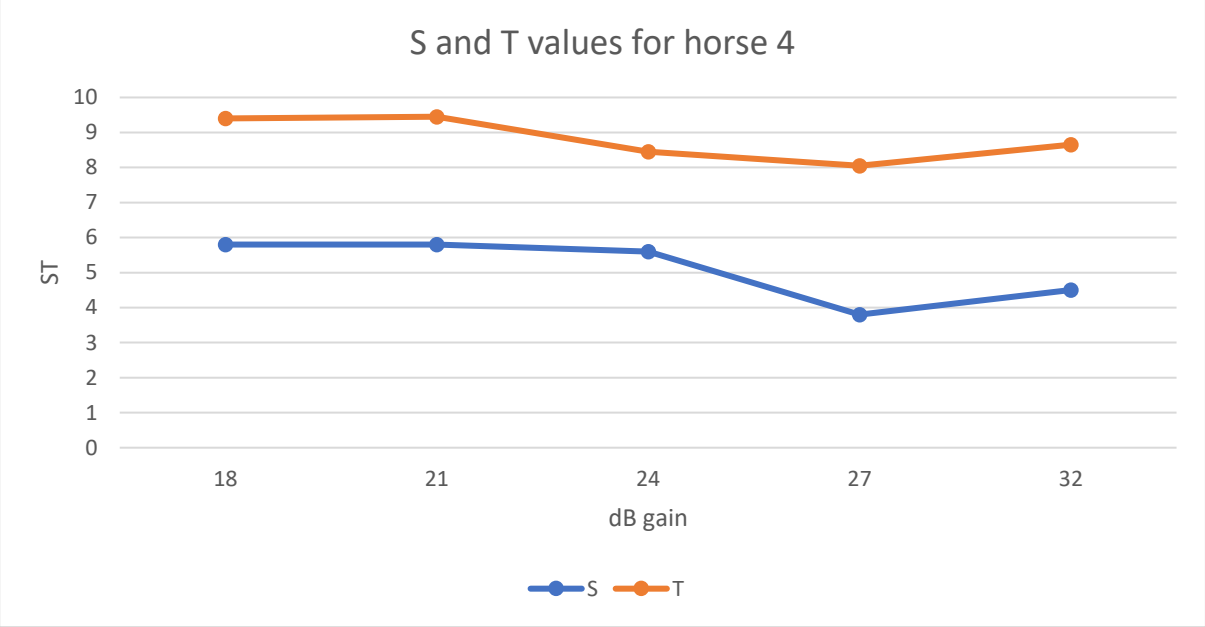
As the study by Jørgensen (2022) showed that palpation of the joint in order to assess the horse’s hypermobility status is too subjective, and differentiating between natural hypermobility and forced hypermobility may not be possible, a more reliable assessment tool needs to be established.

2.2 Acoustic myography

Acoustic myography (AMG) can be used to assess muscle function in real time (Harrison, 2018), and thereby give an assessment of how the muscle is working, through the sound the muscle makes when contracting. AMG can detect how many signals are fired to activate the muscle and how

many muscle fibers are recruited, giving a reliable assessment of how hard the muscle is working. This is measured through the S and T values created, with S being the amplitude of the muscle signal (spatial summation) and T being the frequency of the signal recruiting the muscle fibers (temporal summation). See graph 2.2.1 for an example of the S and T values measured.

By defining hypermobility as a change in the connective tissue leading to lax ligaments, diagnosing through muscle activity should be possible, as the muscle activity should be higher than in non-hypermobile horses due to the extra work of stabilizing the joints. Some muscle groups could be more reliable to measure, due to myofascial kinetic lines, compensation, and easy accessibility.



Graph 2.2.1: The S (spatial summation) and T (temporal summation) values (mean of 'backing up' + 'walk') for horse 4 in the five amplitudes used in the study.

2.3 Suitable muscles

In the study done by Jørgensen (2022), it was found that AMG may be used to measure muscle activity, although the muscle *gluteus medius* used in the study may not be suitable for measuring hypermobility, as the muscle is used to create force and not to stabilize the horse.

For a muscle to be suitable for measuring and assessing hypermobility it must participate in stabilizing the horse, making the difference in muscle activity detectable. A hypermobile horse should in theory have increased muscle activity compared to a non-hypermobile horse, as the

muscle is doing the ligaments' work. To assess the muscle, it must be easily accessible under the skin, so that a sensor can measure it. A muscle lying under another muscle is not preferable, as the acoustic properties of the muscle makes it difficult to interpretret the AMG resulst accurately.

Ulnaris lateralis, *biceps femoris*, *gluteus medius*, and *extensor carpi radialis*, see picture 3.1, are all muscle-groups accessible directly under the skin. *Ulnaris lateralis*, *biceps femoris*, and *extensor carpi radialis* may be used to stabilize the hypermobile horse to a greater extent than in a non-hypermobile horse.

2.3.1 Ulnaris lateralis and extensor carpi radialis

The carpus joint of the horse has several stabilizing ligaments, preventing the structure from drifting sideways and keeping the small bones in place. When subjected to hypermobility, these ligaments are lax, and thereby lose their stabilizing effect. The muscles attached to the carpus, humerus, and cannon bone (including surrounding bone structures like the splint bone), should therefore act as an extra stabilizer, being more active in a hypermobile horse.

The *Ulnaris lateralis* and *extensor carpi radialis* are both placed on the front limb of the horse, and responsible for moving the carpus joint. The muscles attach on each side of the carpus joint, flexing and extending the joint, and locking it in place in weight carrying phases. The *ulnaris lateralis* flexes the carpus and the *extensor carpi radialis* extends.

In the hypermobile horse, it could be possible that these muscles will help stabilize the carpus joint even more, keeping the carpus in place even when standing still. When moving, the muscles should be more active in the hypermobile horse, than in the non-hypermobile, due to the extra workload of both creating movement, force, and increasing stability. In the hypermobile horse, *ulnaris lateralis* should therefore be active even in the extension phase, and *extensor carpi radialis* should be active even in the flexion phase to help stabilize the carpus of the horse, keeping it from overextending or overflexing.

As the front limbs of the horse often carry the majority of the horse's weight, it could be assumed that the joints of the front limbs are subjected to more muscle activity in the hypermobile horse, for support and stabilization. *Ulnaris lateralis* and *extensor carpi radialis* are relatively big and easily accessible muscles, making them suitable for measuring.

Muscles such as the superficial and deep digital flexor muscle are responsible for flexing the pastern and fetlock joint. Both muscles are laying underneath the *ulnaris lateralis*, *flexor carpi*

radialis and *flexor carpi ulnaris* for most parts and are not easily accessed on the horse for measuring, making them less suitable for this study.

2.3.2 Biceps femoris

Biceps femoris is a part of the superficial dorsal line and the spiral line (Schultz, Due, & Elbrønd, 2021), which are part of the myofascial kinetic lines connecting and stabilizing the horse's body. With insertions from the sacral dorsal spine down to the patellar and lateral side of the femur, *Biceps femoris* is a big and easily accessed muscle, suitable for AMG measuring. The *biceps femoris* is responsible for pushing the body forward by extending the hip, hock, and stifle, and can turn the body on the hindquarters by flexing the stifle joint.

Because of the *bicep femoris* being part of the myofascial kinetic lines, the muscle may already be contributing to the stabilization of the horse. This muscle may be subjected to an increased workload in the hypermobile horse, that could be measurable with AMG.

2.3.3 Gluteus medius

The *gluteus medius* is the largest muscle on the horse, responsible for pushing the body forward and kicking out if necessary. It has its origin on the surface of the ilium bone of the pelvis and at the sacrum and can reach as far as the first lumbar vertebra. This big muscle inserts on the trochanter major, and with a small movement the femur is pulled back in a larger arc, like a lever. It takes a lot of power, and the muscle needs to be well anchored.

Gluteus medius is not part of the myofascial kinetic lines and may not be used to increase stability in a non-hypermobile horse, as it is used to create force. In a hypermobile horse, however, it is possible that the workload on the *gluteus medius* is increased.

In the study done by Jørgensen (2022), it was found that the *gluteus medius* may not be a suitable muscle for measuring hypermobility. But in the study the horses were measured while standing still, a phase where the *gluteus medius* should be inactive. As the myofascial kinetic lines may play a big role in stabilizing the horse's body when standing still, the *gluteus medius* would not have been contracting to increase stability, perhaps even in a hypermobile horse. In moving phases, however, the muscle may show a different result.

3. Method

Hypermobility is defined in this master thesis as ligaments missing their supporting abilities around the joints, relying on the muscles to keep the joints in place and stabilizing the body. This should result in more muscle activity, especially when moving and weight carrying.

Every measuring started with acoustic gel (Ekkomarine Medico A/S, Holstebro, Denmark) being applied on the horse where the desired muscle group was easiest to access. A clean sensor was gently placed on the gel and fastened with adhesive tape (Snøgg AS, Kristiansand, Norway) to keep it in place. A CURO device (CURO-Diagnostics Aps, Bagsværd, Denmark) was connected to the sensor through a cord, and the device was put in a small plastic bag and fastened through adhesive tape to the horse just above the sensor. This assured that the gel did not glide down onto the CURO device. The AMG unit was always put in places where it did not bother the horse. Via Bluetooth, the CURO connected to the CURO Equine 2.2.3 app (CURO-Diagnostics ApS, Bagsværd, Denmark) either on a phone or tablet with internet connection for synchronization.

Two different approaches were used:

A preliminary trial measuring different muscle groups trying to find a suitable muscle to use further on. Five horses were used for the preliminary trial, horses 1 to 5.

A full trial where the measurements were used to create a hypermobility score (HM score), using the muscle groups found suitable in the preliminary trial.

The literary works used for this study were found mainly through Google Scholar and the Copenhagen University library search engine REX. All literature found on Google Scholar was also found on REX to make sure it was peer reviewed. Words used to search were: Ehlers-danlos syndrome, Ehlers-Danlos syndrome rare, Ehlers-Danlos in horses, HERDA horse, HERDA common, horse anatomy, acoustic myography, horse myofascial kinetic lines, horse hypermobility, connective tissue collagen structure, horse *ulnaris lateralis*, horse *extensor carpi radialis*, horse *gluteus medius*, horse *biceps femoris*, horse muscle anatomy, proprioception in horses, proprioception hypermobility. Every time ‘horse’ was used, ‘equine’ was used as well.

3.1 Preliminary trial

To create a baseline for the hypermobility test, horses 1-5 were used to test the following muscle groups: *ulnaris lateralis, gluteus medius, biceps femoris* and *extensor carpi radialis*. See figure 3.1.

Extensor carpi radialis and *ulnaris lateralis* were measured on both the right and left side of the horse, whilst *gluteus medius* and *biceps femoris* were only measured on the left side.

The approach when doing the measurements always started as described previously applying the sensor. Five amplification settings, 18-, 21-, 24-, 27- and 32 dB gain were used.

The first measurements were done on the front limbs of horse 1. The horse was asked to do two sequences of: stand (five seconds), back up (five seconds), stand (five seconds), and walk forward (five seconds), ending with a five second stand, see figure 3.2. The 18 dB gain was repeated after the others, to get a reading where the muscles were warmed up.

The S and T values were found through a 5 second cut of the data, where the S and T means for the five second area was found. S and T values were found for all the phases seen in figure 3.2. If a phase was longer than 5 seconds, a five second area of the phase was chosen, looking for as much symmetry between the muscle's activity as possible, preferring higher S and T values for both muscle groups measured.

The results showed that the data from the first and second sequence were representable to each other. Therefore, for the rest of the testing only one sequence was done (stand – backing up – stand – walk – stand). Furthermore, the second measuring with the 18 dB gain was deemed unnecessary and was only done on the five horses in the preliminary trail.

The horses used for the preliminary trial were all from the same stable, with minimum 12 hours of pasture time each day, silage, grass and straw as main food sources supplemented with vitamins. Some of the horses were suspected to be hypermobile before the testing began.

Horse 1: A 16-year-old P.R.E. (Pura Raza Espaniola) gelding, used mainly for dressage and trail, but out of shape. No known illness and no recurrent lameness history. Assessed as being non-hypermobile by a physiotherapist.

Horse 2: A 1½-year-old P.R.E. mare, not in training, and still growing. Has not been assessed by a physiotherapist. Could possibly be hypermobile due to the young age. No known illness and no recurrent lameness history.

Horse 3: A 5-year-old welsh mare, in maintenance, used for pleasure rides, fully grown. Has not been assessed by a physiotherapist. Suspected hypermobile due to observations of movements. No known illness and no recurrent lameness history.

Horse 4: A 2-year-old welsh gelding, bred for showing, not ridden yet. Has not been assessed by a physiotherapist. No known illness and no recurrent lameness history.

Horse 5: A 12-year-old new forest gelding in maintenance, used for western style pleasure rides. Has not been assessed by a physiotherapist. No known illness and no recurrent lameness history.

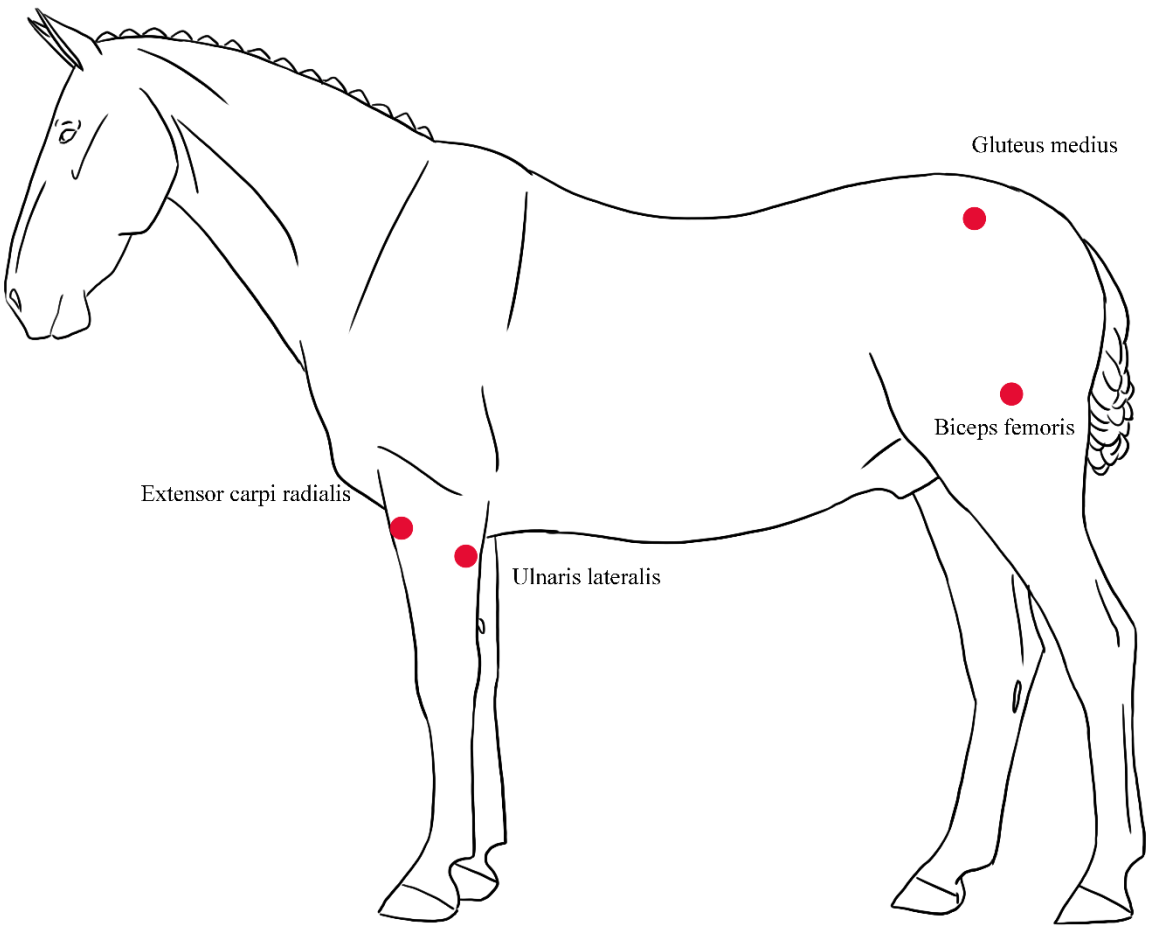


Figure 3.1: Placement of the AMG sensor on the different muscle groups for the preliminary trial: ulnaris lateralis, gluteus medius, biceps femoris and extensor carpi radialis.

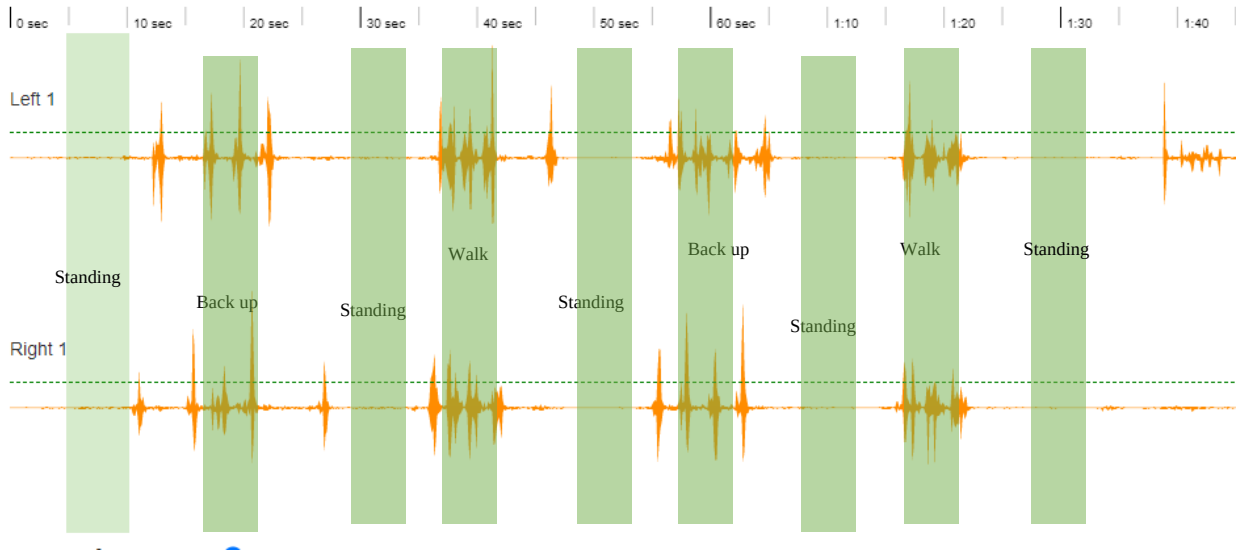


Figure 3.2: Example of a graph from the AMG measurements, showing the five seconds intervals (green) used to pinpoint data from specific phases in the measuring sequence: standing still ('standing'), backing up ('back up' or 'backing up') and walking forward ('walk').

3.2 Full trial

For the full trial only the *ulnaris lateralis* and *extensor carpi radialis* were measured, and only on the left side. Both muscles were measured at the same time, having one sensor on each, using the same methods as described earlier.

The stand – backing up – stand – walk – stand-sequence was measured for the five amplification settings (18-, 21-, 24-, 27-, and 32 dB gain). Twentynine horses were measured including the five preliminary trial horses. The horses were found through Facebook posts. See appendix 1 for details on the horses.

4. Results

The data was assessed using the S and T values, and their means, S being the amplitude of the muscle signal (spatial summation) and T being the frequency of the signal recruiting the muscle fibers (temporal summation) (Vitger, Bruhn-Rasmussen, Pedersen, Fuglsang-Damgaard, & Harrison, 2021). The score 10 was set to be high, meaning that lower scores meant more muscle activity, and higher scores meant less muscle activity (healthy working muscle).

No muscle contractions were registered when 'standing still', giving the score 0 in these phases. As a result, only the measurements from 'backing up' and 'walk' will be shown and further analyzed.

See appendix 1-3 for full lists of results and information on the horses.

4.1 Preliminary trial

Five horses (horses 1-5) were measured for this phase of the study. The muscles measured were: *ulnaris lateralis*, *extensor carpi radialis*, *biceps femoris* and *gluteus medius*. *Ulnaris lateralis* and *extensor carpi radialis* were measured on both the left and right side. They were measured in pairs, the left side front limbs, the right side front limbs, and the left side hindquarters, making sure that the sensors on the muscles in pairs were measuring the same movement.

The ST means (the overall mean of S and T combined) were calculated for each amplitude and were set up into different categories, 'backing up', 'walk' and 'backing up' + 'walk' for each muscle group. The overall ST mean includes both 'backing up' and 'walk'.

4.1.1 Ulnaris lateralis

The data from the *ulnaris lateralis*, see table 4.1.1.1, show that in general when the amplitude is increased, the muscle activities measured increases (lower ST) when the horse is asked to back up. The data also show that for some of the horses, horse 2 and horse 5 especially, there is a difference between the left and right ST, with a difference of 0.7 (horse 2) and 1.2 (horse 5). The mean of the overall difference was 0.7.

The lowest ST mean when 'backing up', including both left and right side, was horse 3 with 4.6, the horse with the highest overall ST mean was horse 4 with 7.9, and the mean of all five horses was 5.9.

When asked to walk, see table 4.1.1.2, a difference between left and right was measured. Here, horses 4 and 5 had the biggest difference with 1.0 for horse 4 and 1.2 for horse 5. The mean of the differences for all the horses was calculated to 0.9.

The lowest ST mean when 'walk', including the left and right side, was horse 3 with 4.1, the highest was horse 4 with 6.5, and the overall mean of the group was 5.3.

Adding the two tables together and calculating the mean can be seen in table 4.1.1.3. Here, horses 3 and 5 have the biggest difference between the left and right side.

The combined ST mean from both left and right and 'backing up + walk' (grey squares in table 4.1.1.3), will be used to make a hypermobility score and will be analyzed further in the analysis section. The mean of this group was 5.6.

		Backing up ST mean						
		18	21	24	27	32	Mean	Difference
Horse 1	Left	6.5	7.1	5.6	4.1		**5.8**	**0.6**
	Right	6.3	4.9	5.5	4.7		**5.4**	
	Mean	**6.4**	**6.0**	**5.6**	**4.4**		**5.6**	
Horse 2	Left	3.4	4.8	5.5	5.3	5.2	**4.8**	**0.7**
	Right	7.0	5.4	6.5	5.4	3.4	**5.5**	
	Mean	**5.2**	**5.1**	**6.0**	**5.4**	**4.3**	**5.2**	
Horse 3	Left	6.3	5.8	3.7	2.7		**4.6**	**0.1**
	Right	7.5	4.5	2.3	3.7		**4.5**	
	Mean	**6.9**	**5.2**	**3.0**	**3.2**		**4.6**	
Horse 4	Left	8.6	8.8	8.0	7.0	7.2	**7.9**	**0.1**
	Right	8.6	8.7	7.2	6.8	7.6	**7.8**	
	Mean	**8.6**	**8.8**	**7.6**	**6.9**	**7.4**	**7.9**	
Horse 5	Left	7.6	5.1	5.5	5.1	3.4	**5.3**	**1.2**
	Right	8.6	6.7	8.0	5.2	3.8	**6.5**	
	Mean	**8.1**	**5.9**	**6.8**	**5.2**	**3.6**	**5.9**	
						Mean	**5.9**	**0.7**

Table 4.1.1.1: Collected data from the preliminary trial of horses measured on the ulnaris lateralis when 'backing up'. Shows the ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain, and overall means.

		Walk ST mean						
		18	21	24	27	32	Mean	Difference
Horse 1	Left	7.4	5.4	3.4	2.2		**4.6**	**0.9**
	Right	6.9	6.2	6.1	2.8		**5.5**	
	Mean	**7.2**	**5.8**	**4.8**	**2.5**		**5.1**	
Horse 2	Left	6.2	6.1	6.3	5.9	4.6	**5.8**	**0.7**
	Right	7.8	5.3	5.4	4.7	2.4	**5.1**	
	Mean	**7.0**	**5.7**	**5.9**	**5.3**	**3.5**	**5.5**	
Horse 3	Left	6.6	4.5	3.6	2.6		**4.3**	**0.5**
	Right	6.5	4.4	2.3	2.3		**3.9**	
	Mean	**6.6**	**4.5**	**3.0**	**2.5**		**4.1**	
Horse 4	Left	6.6	6.5	6.1	4.9	6.0	**6.0**	**1.0**
	Right	7.7	8.4	7.6	7.1	4.4	**7.0**	
	Mean	**7.2**	**7.5**	**6.9**	**6.0**	**5.2**	**6.5**	
Horse 5	Left	7.0	6.5	4.7	3.6	1.5	**4.7**	**1.2**
	Right	7.8	7.3	5.7	4.8	3.7	**5.9**	
	Mean	**7.4**	**6.9**	**5.2**	**4.2**	**2.6**	**5.3**	
						Mean	**5.3**	**0.9**

Table 4.1.1.2: Collected data from the preliminary trial of the horses' ulnaris lateralis measured when walking ('walk'). Shows the ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain, and overall means.

		Overall (walk + backing up) ST mean						
		18	21	24	27	32	Mean	Difference
Horse 1	Left	7.0	6.3	4.5	3.2		**5.2**	**0.2**
	Right	6.6	5.6	5.8	3.8		**5.4**	
	Mean	**6.8**	**5.9**	**5.2**	**3.5**		**5.3**	
Horse 2	Left	4.8	5.5	5.9	5.6	4.9	**5.3**	**0.0**
	Right	7.4	5.4	6.0	5.1	2.9	**5.3**	
	Mean	**6.1**	**5.4**	**5.9**	**5.3**	**3.9**	**5.3**	
Horse 3	Left	6.5	5.2	3.7	2.7		**4.5**	**0.7**
	Right	7.0	4.5	2.3	3.0		**4.2**	
	Mean	**6.7**	**4.8**	**3.0**	**2.8**		**4.3**	
Horse 4	Left	7.6	7.7	7.1	6.0	6.6	**7.0**	**0.4**
	Right	8.2	8.6	7.4	7.0	6.0	**7.4**	
	Mean	**7.9**	**8.1**	**7.2**	**6.5**	**6.3**	**7.2**	
Horse 5	Left	7.3	5.8	5.1	4.4	2.5	**5.0**	**1.2**
	Right	8.2	7.0	6.9	5.0	3.8	**6.2**	
	Mean	**7.8**	**6.4**	**6.0**	**4.7**	**3.1**	**5.6**	
						Mean	**5.6**	**0.5**

Table 4.1.1.3: Overall ST mean ('backing up' + 'walk') of the collected data on the ulnaris lateralis. Shows the ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain, and overall means.

4.1.2 Extensor carpi radialis

The results for the *extensor carpi radialis*, see table 4.1.2.1, showed that when backing up, the ST values decreased when the amplitude was increased, meaning more muscle activity detected. A difference in muscle activity was measured, and on average there was a difference of 1.7 between the left and right side. Horse 3 had the biggest difference with 3.0, and horse 4 the lowest with 0.4.

The mean ST was 5.5. Horse 5 had the lowest ST mean with 4.4, and horse 4 had the highest with 6.4.

'Walk', see table 4.1.2.2, has some of the same tendencies, but with a lower ST mean of 4.7 and a lower difference (1.3) between the left and right side. Horse 3 had the lowest ST with 3.5 and horse 1 had the highest with 6.5.

The overall means of 'backing up' + 'walk', see table 4.1.2.3 gave a mean of 5.1, and an overall difference between left and right of 1.3. Horse 3 had the lowest ST mean of 4.2 and horse 1 had the highest with 6.1.

Horse		Backing up						
		18	21	24	27	32	Mean	Difference
Horse 1	Left	8.5	7.2	6.5	4.2		**6.6**	**1.7**
	Right	6.1	5.5	4.4	3.8		**5.0**	
	Mean	**7.3**	**6.4**	**5.5**	**4.0**		**5.8**	
Horse 2	Left	7.7	7.3	7.2	6.4	4.2	**6.6**	**1.6**
	Right	6.8	5.9	5.9	2.9	3.3	**5.0**	
	Mean	**7.3**	**6.6**	**6.6**	**4.7**	**3.8**	**5.8**	
Horse 3	Left	5.4	5.1	1.8	1.6		**3.5**	**3.0**
	Right	8.1	6.5	5.6	5.6		**6.5**	
	Mean	**6.8**	**5.8**	**3.7**	**3.6**		**5.0**	
Horse 4	Left	7.6	7.6	5.9	6.1	5.7	**6.6**	**0.4**
	Right	6.8	6.3	6.2	5.8	5.8	**6.2**	
	Mean	**7.2**	**7.0**	**6.1**	**6.0**	**5.8**	**6.4**	
Horse 5	Left	5.6	5.3	2.5	1.0	3.6	**3.6**	**1.7**
	Right	5.9	7.3	4.7	3.6	4.8	**5.3**	
	Mean	**5.8**	**6.3**	**3.6**	**2.3**	**4.2**	**4.4**	
						Mean	5.5	1.7

Table 4.1.2.1: Collected data from the preliminary trial of horses measured on the extensor carpi radialis when 'backing up'. Shows the ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain, and overall means.

Horse		Walk						
		18	21	24	27	32	Mean	Difference
Horse 1	Left	7.7	7.1	6.2	4.8		**6.5**	**0.0**
	Right	8.3	7.1	6.2	4.3		**6.5**	
	Mean	**8.0**	**7.1**	**6.2**	**4.6**		**6.5**	
Horse 2	Left	6.4	6.0	6.0	3.9	1.9	**4.8**	**1.2**
	Right	7.0	4.7	4.7	0.9	0.8	**3.6**	
	Mean	**6.7**	**5.4**	**5.4**	**2.4**	**1.4**	**4.2**	
Horse 3	Left	3.2	0.9	1.7	1.1		**1.7**	**3.6**
	Right	7.1	5.3	4.7	4.0		**5.3**	
	Mean	**5.2**	**3.1**	**3.2**	**2.6**		**3.5**	
Horse 4	Left	7.5	5.7	5.6	4.9	4.9	**5.7**	**1.1**
	Right	7.3	5.3	3.2	4.0	3.5	**4.7**	
	Mean	**7.4**	**5.5**	**4.4**	**4.5**	**4.2**	**5.2**	
Horse 5	Left	7.0	6.2	3.8		2.3	**4.8**	**0.7**
	Right	6.6	4.0	4.2	2.3	3.4	**4.1**	
	Mean	**6.8**	**5.1**	**4.0**	**2.3**	**2.9**	**4.2**	
						Mean	4.7	1.3

Table 4.1.2.2: Collected data from the preliminary trial, measured on the extensor carpi radialis when walking ('walk'). Shows the ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain, and overall means.

Horse		Overall (backing up + walk) ST mean						
		18	21	24	27	32	**Mean**	Difference
Horse 1	Left	8.1	7.2	6.4	4.5		**6.5**	**0.8**
	Right	7.2	6.3	5.3	4.1		**5.7**	
	Mean	**7.7**	**6.7**	**5.8**	**4.3**		**6.1**	
Horse 2	Left	7.1	6.7	6.6	5.2	3.1	**5.7**	**1.4**
	Right	6.9	5.3	5.3	1.9	2.1	**4.3**	
	Mean	**7.0**	**6.0**	**6.0**	**3.5**	**2.6**	**5.0**	
Horse 3	Left	4.3	3.0	1.8	1.4		**2.6**	**3.3**
	Right	7.6	5.9	5.2	4.8		**5.9**	
	Mean	**6.0**	**4.5**	**3.5**	**3.1**		**4.2**	
Horse 4	Left	7.6	6.7	5.8	5.5	5.3	**6.2**	**0.7**
	Right	7.1	5.8	4.7	4.9	4.7	**5.4**	
	Mean	**7.3**	**6.2**	**5.2**	**5.2**	**5.0**	**5.8**	
Horse 5	Left	6.3	5.8	3.2	1.0	3.0	**4.2**	**0.5**
	Right	6.3	5.7	4.5	3.0	4.1	**4.7**	
	Mean	**6.3**	**5.7**	**3.8**	**2.3**	**3.5**	**4.3**	
						Mean	5.1	1.3

Table 4.1.2.3: Overall ST mean ('backing up' + 'walk') of the collected data on the extensor carpi radialis. Shows the ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain, and overall means.

4.1.3 Gluteus medius

The results from the *gluteus medius* measurements, see table 4.1.3.1, showed a general lower muscle activity (higher ST) than seen in the *ulnaris lateralis* and *extensor carpi radialis*. The ST mean was 7.2, with horses 3 and 5 under this mean, and with the lowest ST values of 5.7 for horse 3 and 6.6 for horse 5.

Also calculated, for comparison, was the ST mean for 'backing up' with 6.9, and 'walk' with 7.6. Some of the S and T values were lost.

Horse		*Gluteus medius*						
		18	21	24	27	32	Mean	Difference
Horse 1	Back	8.9	6.4	7.5	7.7		7.6	0.4
	Walk	5.2	7.5	7.5	8.6		7.2	
	Mean	**7.1**	**7.0**	**7.5**	**8.2**		**7.4**	
Horse 2	Back		8.1	8.9	7.6	7.1	7.9	0.2
	Walk				8.2	8	8.1	
	Mean	**0.0**	**8.1**	**8.9**	**7.9**	**7.6**	**8.0**	
Horse 3	Back	7.4	2.8	7.1	4.5		5.5	0.5
	Walk	8.7	2.9	5.9	6.2		5.9	
	Mean	**8.1**	**2.9**	**6.5**	**5.4**	**0.0**	**5.7**	
Horse 4	Back			8.5	7.6	8.7	8.3	0.5
	Walk				8.5	9	8.8	
	Mean			**8.5**	**8.1**	**8.9**	**8.5**	
Horse 5	Back				7.2	8.1	5.1	2.9
	Walk				8.5	7.5	8.0	
	Mean				**7.9**	**7.8**	**6.6**	
Mean							**7.2**	**0.9**

Table 4.1.3.1: Collected data from the preliminary trial of the gluteus medius, calculated into ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain for backing up ('backing up') and walking forward ('walk'), and overall means.

4.1.4 Biceps femoris

In table 4.1.4.1 the ST means from the *biceps femoris* can be seen. The results show that the *biceps femoris* was less active, with a ST mean of 6.6, compared to the front limb muscles (5.6 for the *ulnaris lateralis* and 5.1 for the *extensor carpi radialis*). It can also be seen that except in horse 3, backing up seems to require more muscle engagement than walking forward.

Horse 1 has the biggest difference between 'backing up' (6.0) and 'walk' (7.0). Horse 3 has the lowest ST mean with 5.3.

Horse		*Biceps femoris*						
		18	21	24	27	32	Mean	Difference
Horse 1	Back	7.5	4.6	5.2	6.8		6.0	1.0
	Walk	7.9	6.5	7	6.7		7.0	
	Mean	**7.7**	**5.6**	**6.1**	**6.8**	**0.0**	**6.5**	
Horse 2	Back		6.2	6.8	5.6	3.5	5.5	0
	Walk		6.8	6.1	5.4	3.7	5.5	
	Mean	**0.0**	**6.5**	**6.5**	**5.5**	**3.6**	**5.5**	
Horse 3	Back	0	6.7	7.5	8.3		5.6	0.4
	Walk	0	5.5	7.2	7.5		5.1	
	Mean	**0.0**	**6.1**	**7.4**	**7.9**	**0.0**	**5.3**	
Horse 4	Back	8.5	8	6.2	5.6	5.3	8.4	0.5
	Walk	8.2	7.9	7.2	6.4	6	8.9	
	Mean	**8.4**	**8.0**	**6.7**	**6.0**	**5.7**	**8.7**	
Horse 5	Back	6	6.6	5.7	4.1	4.1	6.6	0.7
	Walk	7.1	7.1	5.4	4.3	5.2	7.3	
	Mean	**6.6**	**6.9**	**5.6**	**4.2**	**4.7**	**7.0**	
Mean							**6.6**	**0.5**

Table 4.1.4.1: Collected data from the preliminary trial of the biceps femoris, calculated into ST means for the amplitudes 18-, 21-, 24-, 27-, and 31 dB gain for backing up ('back') and walking forward ('walk'), and overall means.

4.2 Full trial

An overall mean (n=29) was created by calculating the ST mean from both *extensor carpi radialis* and *ulnaris lateralis*, using the 'backing up' and 'walk' phase, in all five dB gains. 29 horses x 2 muscle groups x 2 moving phases = 116 ST means, see table 5.5.3. Graph 5.5.4 shows the overall means for the two muscle groups and the two moving phases with their standard deviations, showing that they overlap and can be pulled into one value or mean.

This overall mean was used to create a hypermobility score (HM score) and was calculated for each horse. Afterwards the average HM score was calculated (5.8). Every horse with a HM-score lower than 5.8 was assessed as having a higher muscle activity level than average, and as possibly being hypermobile or borderline.

To separate the possible hypermobile horses from the borderline, a mean was calculated for all the horses with a lower HM score than 5.8. This mean (5.1) was now set as the upper limit for hypermobility, meaning that horses with a HM score equal to or lower than 5.1 were assessed as being hypermobile due to the extent of the muscle activity. This also served as the lower limit for the borderline cases.

To create an upper limit for the borderline the mean HM score for all the horses, including the hypermobile, was used, setting the limit of the borderline to 5.2 – 5.8.

Based on the upper and lower limits for hypermobility and borderline, a score system was made, see table 4.2.1. All the horses were assessed using this score system, and assessed as being non-hypermobile, borderline, or hypermobile, see table 4.2.2 and graph 4.2.1.

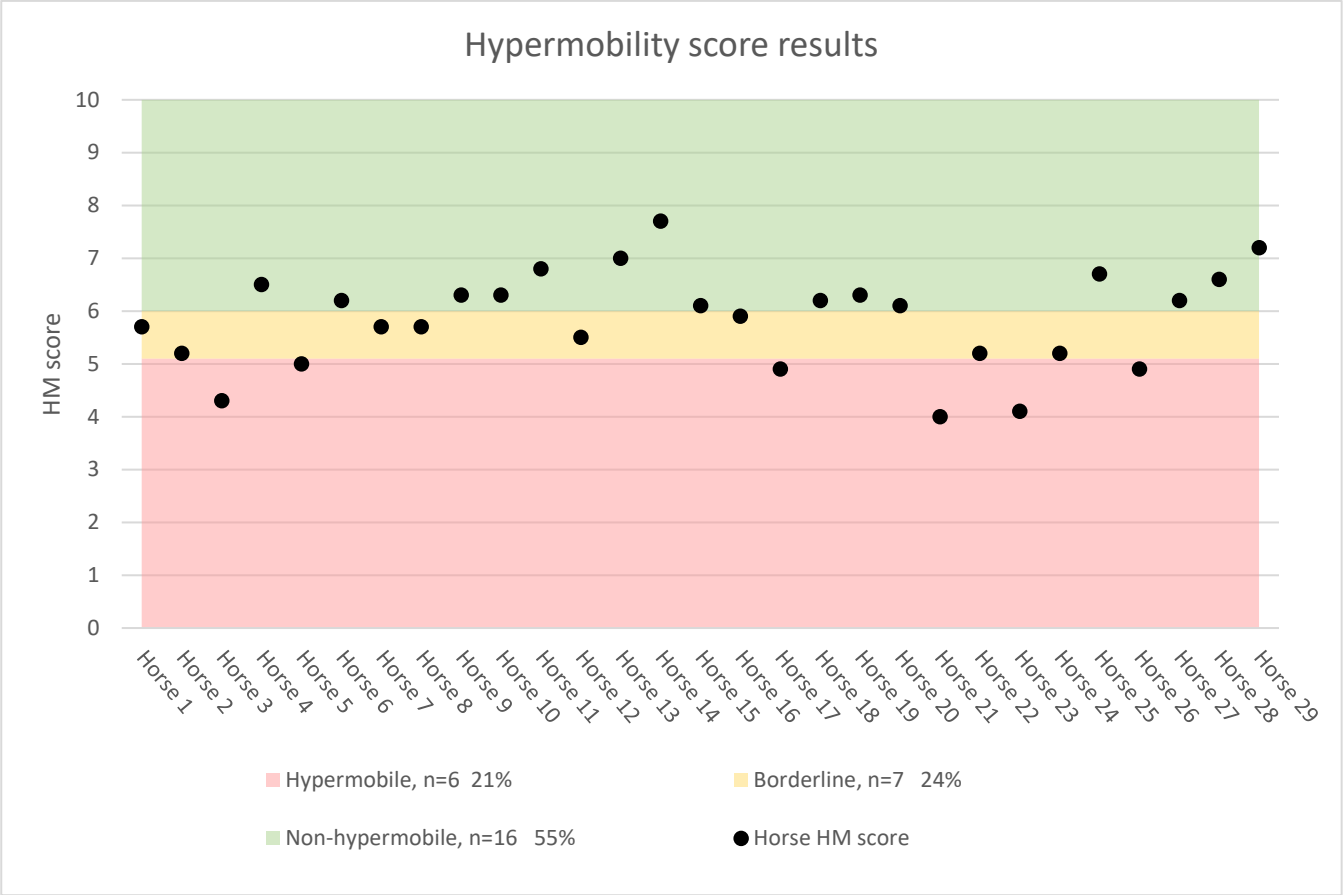
Out of the 29 horses assessed in this report, 21% (n=6) were assessed as being hypermobile, 24% (n=7) as being borderline and 55% (n=16) as being non-hypermobile.

HM score	
Non-hypermobile	≥5.9
Borderline	5.2-5.8
Hypermobile	≤5.1

Table 4.2.1: Hypermobility score (HM score) indicating the margins for each status.

ST mean			dB gain			
	18	*21*	*24*	*27*	*32*	HM score
Horse 1	7.3	6.3	5.5	3.9		5.7
Horse 2	6.6	5.7	6.0	4.4	3.3	5.2
Horse 3	6.4	4.7	3.3	3.0		4.3
Horse 4	7.6	7.2	6.2	5.9	5.7	6.5
Horse 5	7.1	6.1	4.9	3.5	3.3	5.0
Horse 6	7.5	6.4	6.0	5.9	5.1	6.2
Horse 7	7.0	6.2	6.0	4.7	4.7	5.7
Horse 8	6.6	6.6	5.6	4.8	4.9	5.7
Horse 9	7.7	7.2	5.9	5.5	5.2	6.3
Horse 10	7.2	6.7	5.7	6.6	5.2	6.3
Horse 11	8.1	7.9	6.7	5.9	5.5	6.8
Horse 12	7.1	6.3	5.1	5.4	3.9	5.5
Horse 13	7.6	8.0	7.2	6.4	5.7	7.0
Horse 14	8.4	7.5	8.0	7.0		7.7
Horse 15	6.5	7.4	6.4	5.8	4.3	6.1
Horse 16	7.6	6.2	5.0	4.5	6.2	5.9
Horse 17		5.7	4.5	4.5		4.9
Horse 18	7.0	6.4	6.3	5.2	6.0	6.2
Horse 19	7.2	6.6	7.0	5.7	5.2	6.3
Horse 20	7.6	6.6	5.6	5.3	5.5	6.1
Horse 21	5.7	4.8	3.6	2.9	3.0	4.0
Horse 22	6.7	6.8	5.0	4.0	3.7	5.2
Horse 23	5.7	4.6	3.8	3.8	2.6	4.1
Horse 24	6.8	5.9	5.5	4.1	3.5	5.2
Horse 25	7.3	7.2	7.3	6.2	5.6	6.7
Horse 26	6.2	6.1	4.3	4.1	3.8	4.9
Horse 27	7.6	7.4	6.6	5.4	4.1	6.2
Horse 28	7.9	7.7	6.0	5.9	5.4	6.6
Horse 29	7.9	8.3	6.9	6.6	6.5	7.2

Table 4.2.2: Overall ST mean (ulnaris lateralis + extensor carpi radialis + 'backing up' + 'walk') for the different dB gains, and the HM score. Colors indicating their assessed hypermobility status: green = not hypermobile, yellow = borderline, and red = hypermobile.



Graph 4.2.1: Final HM score (hypermobility score) of the 29 horses measured. Green area = not hypermobile, yellow area = borderline, and red area = hypermobile.

Breed and gender of the 29 horses were assessed and the percentage distribution was calculated, see table 4.2.3. Eleven different breeds or blends were measured, DV (Danish warmblood, n=8), Icelandic horse (n=6) and PRE (Pura Raza Espanola, n=5) were the three most represented breeds in this study. The other breeds or blends had two or less horses and will not be commented on.

The DV horses (n=8) were assessed as being hypermobile in 38% (n=3) of the horses, and borderline in 13% (n=1). This was the highest percentage of hypermobility in a breed or blend with five or more horses participating in the study.

Looking at the gender distribution of the measured horses, 52% (n=15) were geldings and 48% (n=14) were mares. The percentage of horses assessed as being hypermobile were similar, with 20% (n=3) of geldings and 21% (n=3) of the mares being in that category. In borderline,

however, 13% (n=2) of the geldings were assessed as being in this category, while 36% (n=5) of the mares were assessed as being borderline.

Age will not be commented on, as the range was 2 – 22 years of age, with 0-3 horses in each age, which were assessed as not being sufficient to do reliable statistics. Height will also not be commented further upon in this study, as the study by Jørgensen (2022) showed that the connection between height and hypermobility may lie in the breeds' differences, as there are height standards for most breeds. To do a reliable statistical analysis for both age and height, the number of measured horses needs to be higher.

Breed	Total	Hypermobile		Borderline		Non-hypermobile	
	n	n	%	n	%	n	%
DV	8	3	38%	1	13%	4	50%
Arabian blend	2		0%	1	50%	1	50%
Icelandic horse	6	1	17%	1	17%	4	67%
Lusitano	1	0	0%	0	0%	1	100%
Mustang	1	0	0%	0	0%	1	100%
New forest	1	1	100%	0	0%	0	0%
PRE	5	0	0%	2	40%	3	60%
PRE/warmblood	1	0	0%	0	0%	1	100%
Warmblood blend	1	0	0%	1	100%	0	0%
Welsh	2	1	50%	0	0%	1	50%
Welsh blend	1	0	0%	1	100%	0	0%
Gender							
Gelding	15	3	20%	2	13%	10	67%
Mare	14	3	21%	5	36%	6	43%

Table 4.2.3: The distribution of breed and gender of the 29 horses measured. DV = Danish warmblood, PRE = Pura Raza Espanola.

5. Analysis

The results from the measurements were further calculated and analyzed to give a better understanding of the results.

5.1 Preliminary trial: Difference in muscle groups

Through the measurements from the preliminary trial, the difference between the muscle groups can be seen and compared. The difference in muscle activity between walking (‘walk’) and backing (‘backing up’) within the muscle groups can also be evaluated.

Table 5.1.1 shows the overall ST means of the five amplitudes used for the measurements put together, for the four muscle groups assessed in the preliminary trial. For the *ulnaris lateralis* and *extensor carpi radialis* the ST values are also the mean of the left and right side.

The results show a pattern of muscle activity between the four muscle groups measured in this study. In graph 5.1.1 the *ulnaris lateralis* and *gluteus medius* are less active than *extensor carpi radialis* and *biceps femoris*. The pattern can be seen in both the ‘walk’ phase, graph 5.1.2a and the ‘backing up’ phase, graph 5.1.2b, although it is less monotonous in the ‘backing up’ phase. Through the full trial, which will be analyzed in a later section, it shows that the *ulnaris lateralis* have a higher ST value than the *extensor carpi radialis*, backing up the findings from the preliminary trial.

Horse 1, however, breaks the pattern, with its *extensor carpi radialis* being less active than the *ulnaris lateralis*. Either there is decreased activity in the *extensor carpi radialis* or an increased activity in the *ulnaris lateralis*, or maybe a combination. Whether it is caused by an injury, old or new, or hypermobility is unknown. This horse was assessed as borderline with a HM score of 5.7 near the border to non-hypermobile, which may suggest that the different pattern between the two muscles is not an indication of hypermobility.

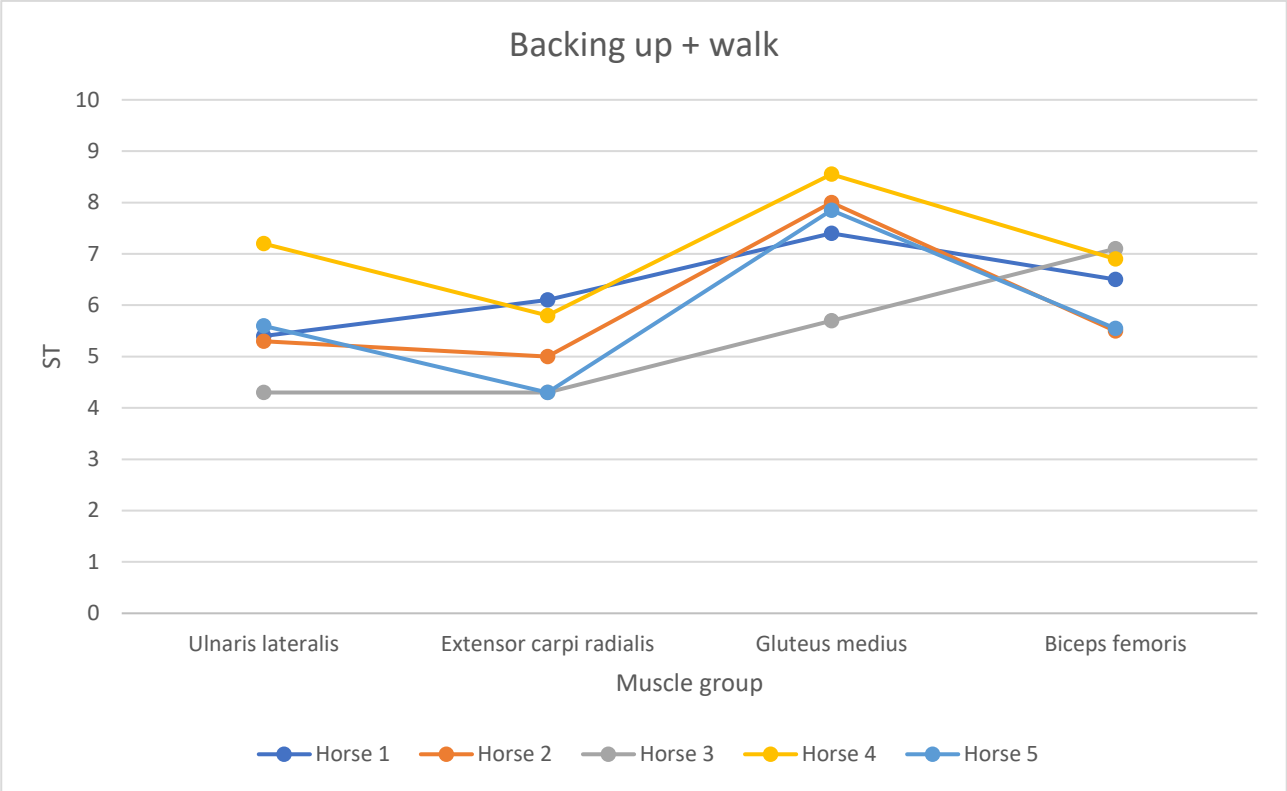
Horse 3 also breaks the pattern with a more active *gluteus medius* than *biceps femoris*. This horse was assessed as being hypermobile with a HM score of 4.3, which could explain the difference between the *gluteus medius* and *biceps femoris*, as the horse could be relying more on the *gluteus medius* for movement.

The *gluteus medius* may therefore be a reliable muscle for hypermobility measurements, if the muscle is measured when moving the limb, as the results from this study may indicate a possible *gluteus medius* compensation for the *biceps femoris*. Graph 5.1.1 shows that in horse 3

(assessed as hypermobile) the *gluteus medius* is more active (ST = 5.7) than the biceps femoris (ST= 7.1), where in the other horses it is the other way around. Horse 3 also has the highest ST for the *biceps femoris* (lowest activity) and the lowest ST for the *gluteus medius* (high activity), which could be an indication of muscle compensation. Both muscles are responsible for extending the femur, pushing the limb back and the body forward. The *biceps femoris* are a part of the myofascial kinetic lines, and therefore a part of the horse's stabilization system. In a hypermobile horse, the stabilization system may be overused, leading to *biceps femoris* being overworked, which could cause a compensation reaction in the *gluteus medius*.

Mean ST				
HM score	*Ulnaris lateralis*	*Extensor carpi radialis*	*Gluteus medius*	*Biceps femoris*
Horse 1	5.4	6.1	7.5	6.6
Horse 2	5.3	5.0	8.1	5.5
Horse 3	4.3	4.3	5.7	7.1
Horse 4	7.2	5.8	8.5	7.0
Horse 5	5.6	4.3	7.7	5.5
Backing up ST				
HM score	*Ulnaris lateralis*	*Extensor carpi radialis*	*Gluteus medius*	*Biceps femoris*
Horse 1	5.6	5.8	7.6	6.0
Horse 2	5.2	5.8	7.9	5.5
Horse 3	4.9	5.0	5.5	5.6
Horse 4	7.9	6.4	8.3	8.4
Horse 5	5.9	4.4	5.1	6.6
Walk ST				
HM score	*Ulnaris lateralis*	*Extensor carpi radialis*	*Gluteus medius*	*Biceps femoris*
Horse 1	5.1	6.5	7.2	7.0
Horse 2	5.5	4.2	8.1	5.5
Horse 3	4.1	3.5	5.9	5.1
Horse 4	6.5	5.2	8.8	8.9
Horse 5	5.3	4.2	8.0	7.3

Table 5.1.1: ST values from the preliminary trial, showing the overall mean of the ST values (amplitudes 18-, 21-, 24-, 27-, and 31 dB gain) from four muscle groups. The 'Mean' ST is the mean of both the 'backing up' and 'walk' ST values. Red color = assessed as hypermobile, yellow = assessed as borderline, green = assessed as non-hypermobile.



Graph 5.1.1: The difference between muscle activity in four muscle groups for the five preliminary trial horses. ST = 10 indicating low activity, and ST = 1 indicating high activity.

5.2 Preliminary trial: Difference in backing up and walking forward

The difference in muscle activity between backing up and walking forward was individual throughout the five preliminary trial horses to some extent. As can be seen in table 5.2.1, the biggest difference in muscle activity was in the *extensor carpi radialis*, while the muscle with the lowest difference was the *gluteus medius*. The *extensor carpi radialis* was in general more active in the 'walk' phase than in the 'backing up' phase, see graphs 5.1.2a-b, except in horse 1, who had a generally lower muscle activity (high ST) in the *extensor carpi radialis* than the other horses.

No correlation was found between the difference in muscle activity, both in the 'backing up' and 'walk' phases, and hypermobility. Graphs 5.1.3 a-e show the difference for each horse, and it can be seen that the two horses assessed as hypermobile (horse 3 and 5) do not have similar graphs, neither do horses 1 and 2, who were assessed as borderline. Horse 4, which was assessed as non-hypermobile, does not have a graph that differs significantly from the others.

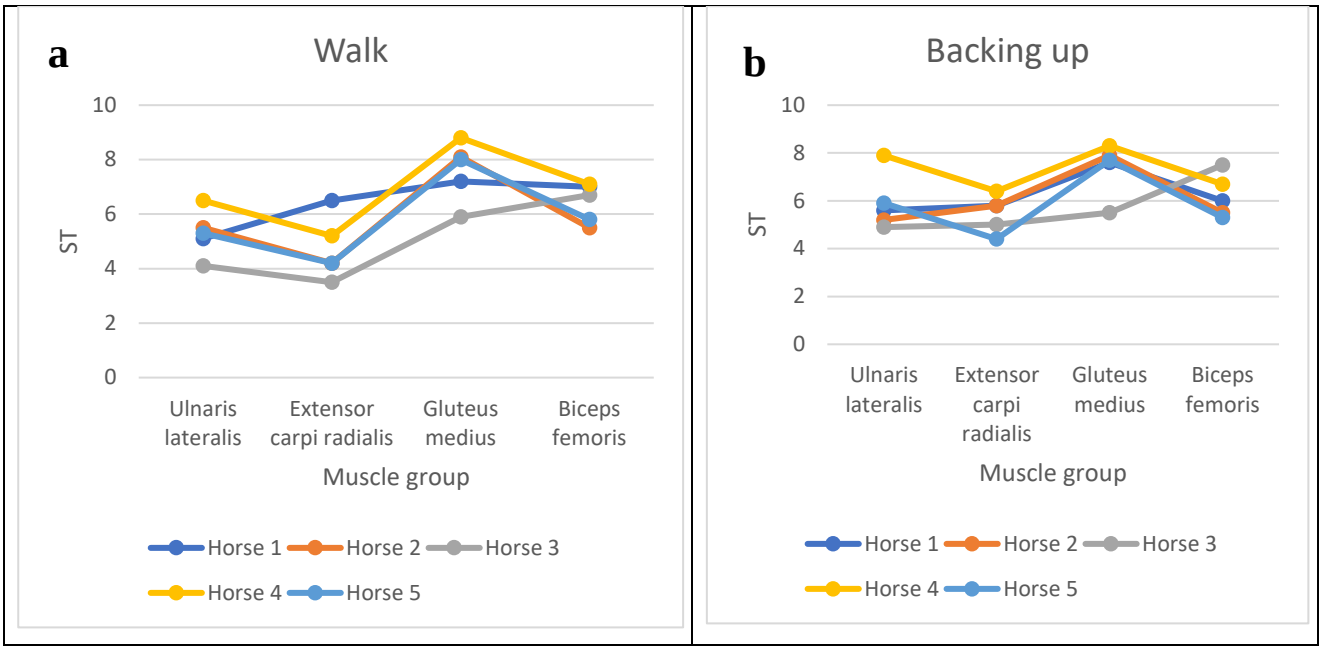
Even though the difference between backing up and walking forward may not give any indication of hypermobility, it still gives an indication of how a horse moves its body. There could

be a difference between the individual horses due to preference, as horses do not use their body the same way, thereby burdening the muscle groups differently. Horses are often less used to backing up as they are walking forward, as they do not do this as often, this could result in a more uneven use of the muscles, as the whole movement will not be as smooth and will require more of an effort compared to walking forward. Backing straight backwards could also be difficult for an untrained horse, as the horse has a blind spot, and the training may not be repeated as much as needed for the horse to be comfortable with backing up, making it resistant.

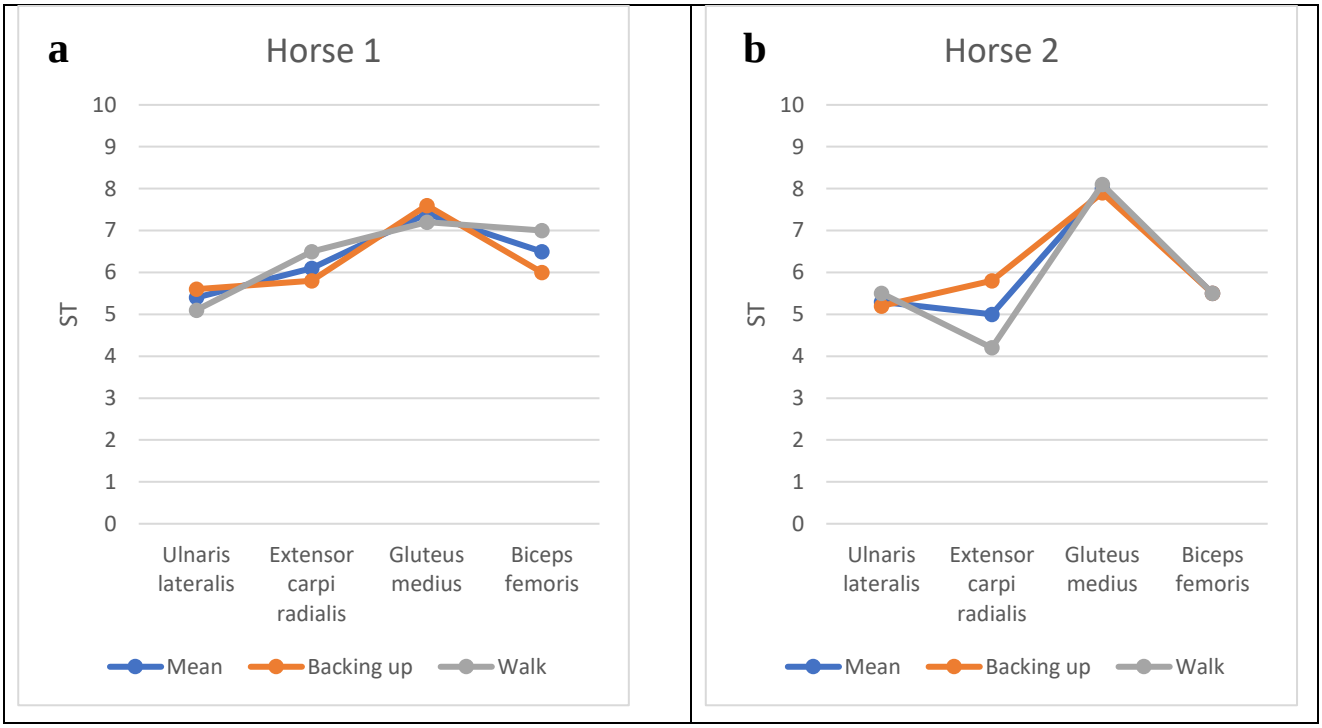
As there is no clear difference between 'backing up' and 'walk', even in the hypermobile, the borderline and non-hypermobile horses, it could be suggested that the 'backing up' phase is unnecessary when assessing hypermobility.

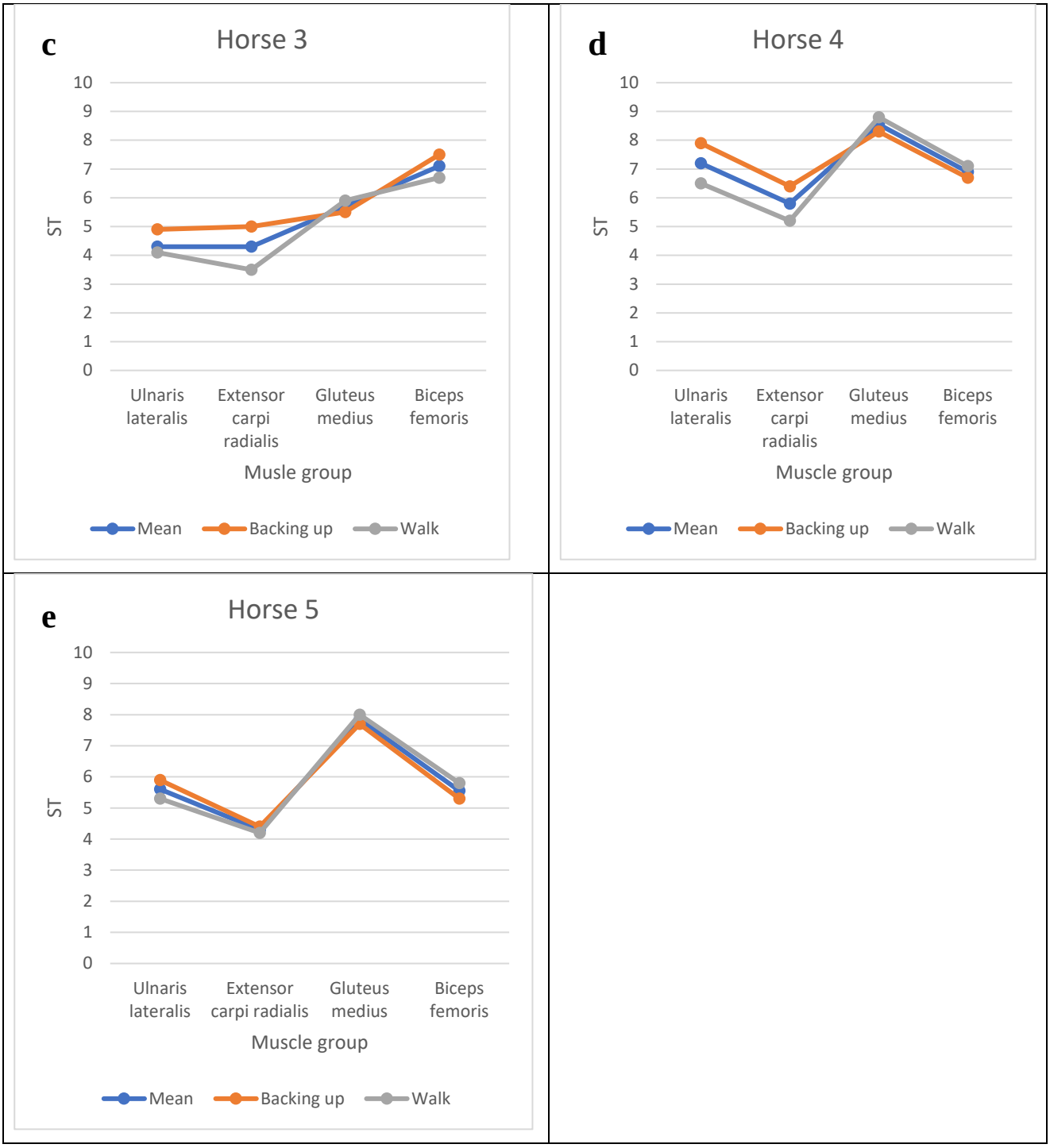
Difference in ST	*Ulnaris lateralis*	*Extensor carpi radialis*	*Gluteus medius*	*Biceps femoris*
Horse 1	0.5	0.7	0.4	1.0
Horse 2	0.3	1.6	0.2	0.0
Horse 3	0.8	1.5	0.4	0.8
Horse 4	1.4	1.2	0.5	0.4
Horse 5	0.6	0.2	0.3	0.5
Mean	0.7	1.0	0.4	0.5

Table 5.2.1: Difference in ST values for the muscle activity ('backing up' + 'walk') in four muscle groups in the five preliminary trial horses. ST = 10 indicating low activity, and ST = 1 indicating high activity.



Graph 5.1.2: The difference between muscle activity in four muscle groups for the five preliminay trial horses. ST = 10 indicating low activity, and ST = 1 indicating high activity. a showing the results from 'walk' and b showing the results from 'backing up'.





Graph 5.1.3: a-e: The difference between 'backing up' and 'walk' for the four muscle groups measured in the preliminary trial, for each of the five horses participating. ST indicating the muscle activity, high ST = low activity, and low ST = high activity.

5.3 Preliminary trial: Difference in the left and right side of the front limb

Table 5.3.1 shows the results and mean of the five preliminary trial horses, and the difference between the left and right side measurements.

As seen in graph 5.3.1 and table 5.3.1, the two horses assessed as being hypermobile are also the ones with the biggest difference between left and right, showing a possible sign of muscle compensation. Horse 3's mean is assessed as being in the hypermobile category with both the right (5.1) and left (3.6) front limb, while horse 5 is assessed as borderline on the right side (5.5) and hypermobile on the left side (4.6). This could mean that measurements on both sides need to be done, to give a more accurate assessment on the horse's hypermobility status.

As earlier mentioned, the *extensor carpi radialis* had the highest difference in ST values in the 'backing up' and 'walk' phases. When looking at the muscle activity in the left and right side, it is seen that the *extensor carpi radialis* has the biggest difference as well, with a ST difference mean of 1.3 (see table 4.1.2.3), where the ST difference mean is 0.5 (table 4.1.1.3) for the *ulnaris lateralis*. The difference in left and right for the *extensor carpi radialis* could indicate that this muscle is subjected to preference by the individual horse, making it unreliable to measure only on one side.

Comparing the left and right side of the *ulnaris lateralis* and *extensor carpi radialis* also shows that the muscle activity is not monotonous. For three of the horses (horse 1, horse 3 and horse 5) there is not a clear left or right side preference between the muscle groups, as graph 5.3.1 shows. For these three horses, there is a pattern where the lowest ST value is on the right side *extensor carpi radialis* and left side *ulnaris lateralis*, or vice versa, showing an individual left or right side preference within the muscle groups. It is unlikely that it is a sign of muscle compensation between the *ulnaris lateralis* and *extensor carpi radialis*, as these two muscle groups do not have the same function.

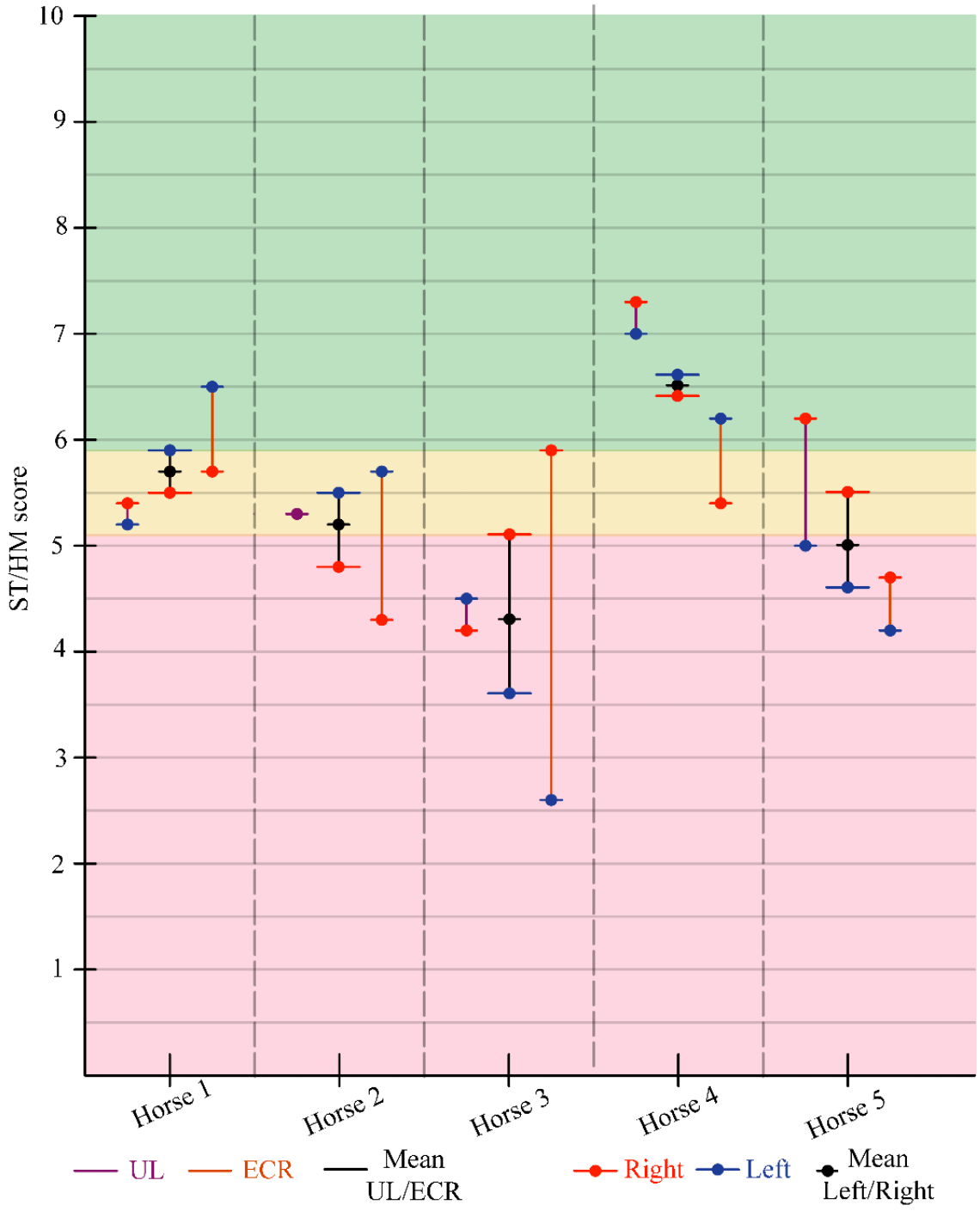
The horses that did not show this were horses 2 and 5. Horse 2 had identical left and right side ST values for the *ulnaris lateralis*. Horse 5, however, had an increased left and right difference in the *ulnaris lateralis* compared to the *extensor carpi radialis* than the other horses. In a later section it will be discussed if this could be a sign of an injury.

Horse 3 had an increased difference between the left and right side *extensor carpi radialis*, see table 5.3.1 and graph 5.3.1. This could show a compensation in the muscle activity in a

hypermobile horse, indicating that an increased difference between the left and right side *extensor carpi radialis* may be more pronounced in a hypermobile horse.

		18	21	24	27	32	Mean	Difference
Horse 1	Left	7.6	6.8	5.5	3.9		**5.9**	0.3
	Right	6.9	6.0	5.6	4.0		**5.6**	
	Mean	**7.3**	**6.3**	**5.5**	**3.9**		**5.7**	
Horse 2	Left	6.0	6.1	6.3	5.4	4.0	**5.5**	0.7
	Right	7.2	5.4	5.7	3.5	2.5	**4.8**	
	Mean	**6.6**	**5.7**	**6.0**	**4.4**	**3.3**	**5.2**	
Horse 3	Left	5.4	4.1	2.8	2.1		**3.6**	1.5
	Right	7.3	5.2	3.8	3.9		**5.1**	
	Mean	**6.4**	**4.7**	**3.3**	**3.0**		**4.3**	
Horse 4	Left	7.6	7.2	6.5	5.8	6.0	**6.6**	0.2
	Right	7.7	7.2	6.1	6.0	5.4	**6.4**	
	Mean	**7.6**	**7.2**	**6.2**	**5.9**	**5.7**	**6.5**	
Horse 5	Left	6.8	5.8	4.2	2.7	2.8	**4.6**	0.9
	Right	7.3	6.4	5.7	4.0	4.0	**5.5**	
	Mean	**7.1**	**6.1**	**4.9**	**3.5**	**3.3**	**5.0**	

Table 5.3.1: Mean of the extensor carpi radialis + ulnaris lateralis ('backing up' + 'walk'), on both left and right side of the horse, in five different amplifications (18-, 21-, 24-, 27-, and 31 dB gain). The HM score (hypermobility score) being the mean on both sides, the difference between them and the overall HM score. The colors show the hypermobility status: green = non-hypermobile, yellow = borderline and red = hypermobile.



Graph 5.3.1: The difference in the ST values for the ulnaris lateralis (UL) and extensor carpi radialis (ECR) in both moving phases ('backing up' + 'walk'), and the difference in the left (blue dot) and right (red dot) side ST means, and the overall mean of the ST value, HM scores (black dots), for horses 1-5 in the preliminary trial. The green area is non-hypermobile (HM score ≥ 5.9), yellow area is borderline (HM score 5.2-5.8) and the red area is assessed as hypermobile (HM score ≤ 5.1)

5.4 Preliminary trial: Sum up and semi conclusion

The difference between the muscle groups indicates a pattern of activity that may be similar in most horses, with the *gluteus medius* being least active, and the *extensor carpi radialis* being the most active in the 'walk' and 'backing up' phases. Horses with significant changes to this pattern could be hypermobile or have an injury, as they may be compensating.

The results in muscle activity between the moving phases 'backing up' and 'walk' only shows a small difference in muscle use, with the *extensor carpi radialis* having the biggest variation in activity. This indicates that 'backing up' is not necessary, as the 'walk' phase is representative for the use of the muscles and is easier for most horses to do without resistance.

Measurements from the left and the right side of the *ulnaris lateralis* and *extensor carpi radialis* showed an increase in the difference for the two sides on the *extensor carpi radialis* compared to the *ulnaris lateralis*. This could indicate that *extensor carpi radialis* is more alternating in its use, making it less reliable to measure as the only muscle group.

Measuring only one muscle group is not reliable as compensation between the muscle groups can not be seen, and possible injuries can not be detected, giving a horse a HM score in the hypermobile area, when the low ST values (high muscle activity) could be caused by compensation in only that muscle.

5.5 Full trial

There were 29 horses participating in the full trial, six of them were assessed as being hypermobile via the HM score. Comparing the 'walk' and 'backing up' ST means for the two muscle groups *ulnaris lateralis* and *extensor carpi radialis*, see table 5.5.1, shows that between 'backing up' and 'walk', the difference was 7% for the *ulnaris lateralis* and 6% for the *extensor carpi radialis*. This indicates that only one of the two moving phases, 'backing up' or 'walk', needs to be measured. As most horses seem to be more comfortable with walking forward, this may be the suitable moving phase to measure.

Comparing the two muscle groups, the difference between 'backing up' and 'walk' were identical, with a difference of 0.4 in both 'backing up' and 'walk', see graph 5.5.2, adding to the conclusion that only one moving phase is needed.

In graph 5.5.4, the difference between the two muscle groups and two moving phases are shown with their standard deviation, showing that the ST or HM scores for each group can be used

individually or pulled together. Keep in mind that these are only measured on the left side of the horse, and if only one muscle group is used the data may not be reliable, as this study has shown that two muscle groups or the left and right side of one muscle group needs to be measured to account for muscle compensation.

However, if only measuring ‘walk’, a new HM score system needs to be calculated, as ‘walk’ has a generally lower ST value (0.4) than ‘backing up’. The HM score system set by this study can be used if both ‘backing up’ and ‘walk’ are measured. Table 5.5.2 shows the HM scores for both moving phases and muscle groups used in the full trial.

The ST mean of the *ulnaris lateralis* and the *extensor carpi radialis* seem symmetric in graph 5.5.2, showing that one muscle group is not pulling the ST mean of ‘backing up’ or ‘walk’ in either direction, indicating that *ulnaris lateralis* and *extensor carpi radialis* is suitable as a pair to measure.

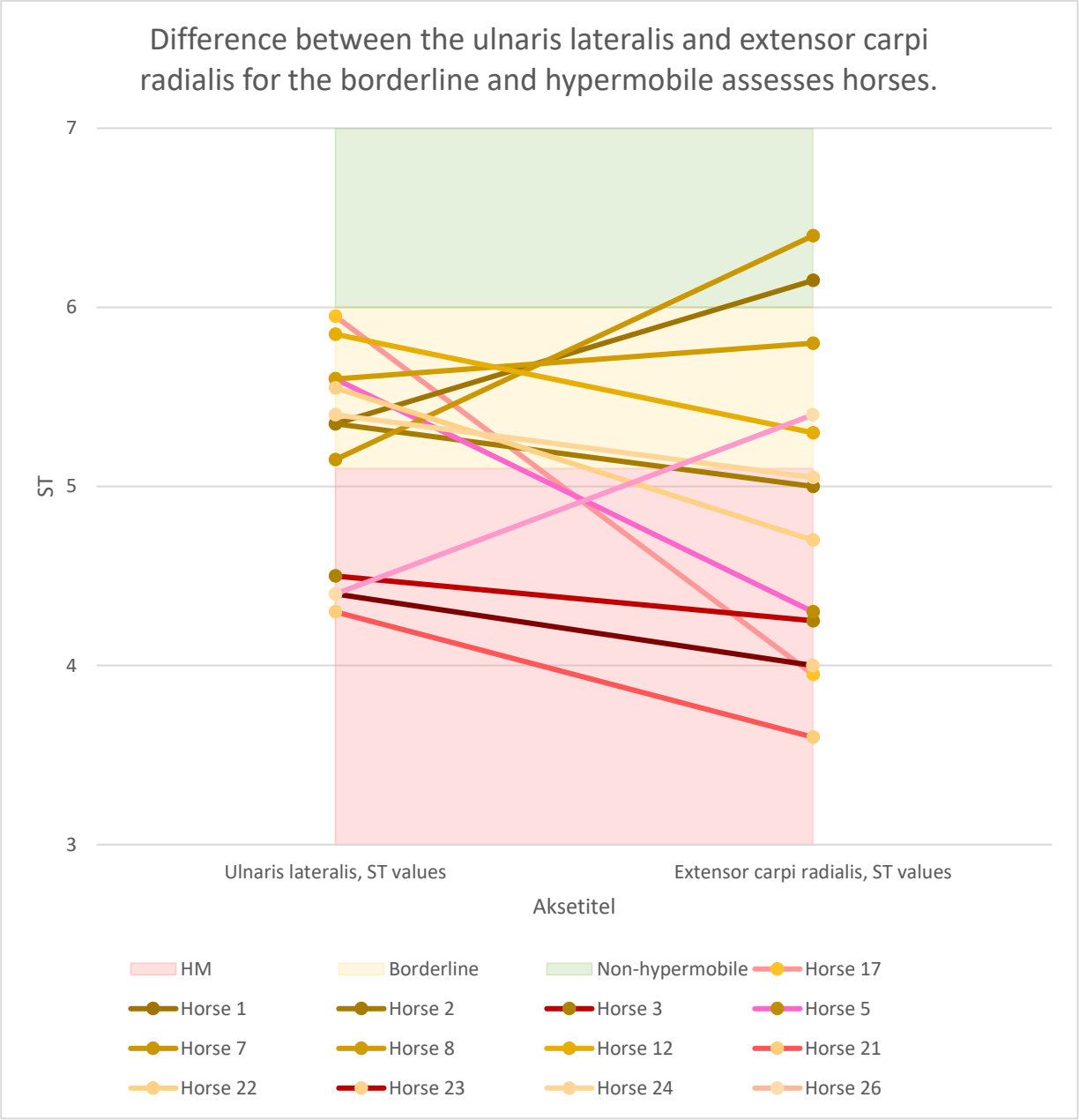
Some horses, however, have an increased difference between the *ulnaris lateralis* and *extensor carpi radialis* ST means, going across from borderline to hypermobile, see graph 5.5.1. Horse 5, horse 17 and horse 26 were all assessed as being hypermobile due to their HM score, but depending on the muscle group all of them had values in both hypermobile and borderline, with horse 17 close to the non-hypermobile area.

This could be an indication of an injury in the horses, or a localized muscle compensation. Increased differences between the muscle groups were also seen in horses assessed as being non-hypermobile and borderline, which could mean that it may be normal and just shows the difference in how the horse is using its body by preference.

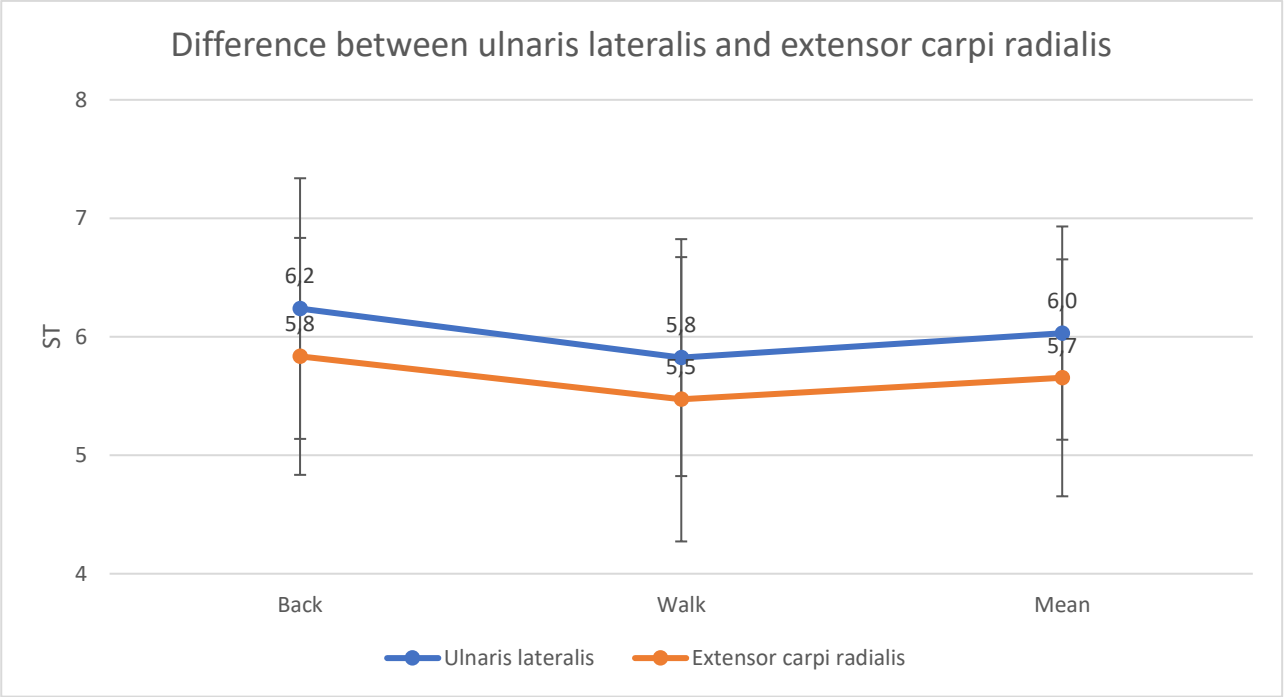
However, there is also the possibility that the increased difference is a sign of an injury of some sorts, and horses with this difference in the borderline and hypermobile area either have a more severe injury, or have had it for a longer time, leaving their muscle unable to restore properly for a longer period. It may not have to be a major injury to the muscle, it could be a small sprain or just being stiff, leaving the muscle sore. It may not even be an injury to the locomotive system, it could be issues such as teeth problems or digestive problems leaving the horse tense because of pain, causing localized compensation in some muscle groups.

	Ulnaris lateralis, ST values				Extensor carpi radialis, ST values			
	Back	Walk	Mean	Diff	Back	Walk	Mean	Diff
Horse 1	5.6	5.1	5.4	0.5	5.8	6.5	6.2	0.7
Horse 2	5.2	5.5	5.4	0.3	5.8	4.2	5.0	1.6
Horse 3	4.9	4.1	4.5	0.8	5.0	3.5	4.3	1.5
Horse 4	7.9	6.5	7.2	1.4	6.4	5.2	5.8	1.2
Horse 5	5.9	5.3	5.6	0.6	4.4	4.2	4.3	0.2
Horse 6	5.5	6.4	6.0	0.9	5.7	7.1	6.4	1.4
Horse 7	5.5	4.8	5.2	0.7	6.2	6.6	6.4	0.4
Horse 8	4.9	6.3	5.6	1.4	5.4	6.2	5.8	0.8
Horse 9	6.7	5.6	6.2	1.1	7.3	5.6	6.5	1.7
Horse 10	6.3	7.0	6.7	0.7	6.3	5.3	5.8	1
Horse 11	6.8	6.9	6.9	0.1	6.5	7.1	6.8	0.6
Horse 12	6.3	5.4	5.9	0.9	5.4	5.2	5.3	0.2
Horse 13	7.9	6.4	7.2	1.5	7.2	6.4	6.8	0.8
Horse 14	7.9	7.3	7.6	0.6	8.0	7.4	7.7	0.6
Horse 15	6.5	7.0	6.8	0.5	5.0	5.7	5.4	0.7
Horse 16	7.2	5.5	6.4	1.7	5.3	5.5	5.4	0.2
Horse 17	5.8	6.1	6.0	0.3	4.5	3.4	4.0	1.1
Horse 18	6.8	6.8	6.8	0	5.8	5.2	5.5	0.6
Horse 19	6.1	6.9	6.5	0.8	6.1	6.2	6.2	0.1
Horse 20	7.4	5.7	6.6	1.7	6.2	5.4	5.8	0.8
Horse 21	4.2	4.4	4.3	0.2	3.8	3.4	3.6	0.4
Horse 22	5.6	5.5	5.6	0.1	4.7	4.7	4.7	0
Horse 23	4.2	4.6	4.4	0.4	4.1	3.9	4.0	0.2
Horse 24	5.9	4.9	5.4	1	5.6	4.5	5.1	1.1
Horse 25	7.0	5.9	6.5	1.1	7.4	6.6	7.0	0.8
Horse 26	5.2	3.6	4.4	1.6	5.4	5.4	5.4	0
Horse 27	6.9	6.1	6.5	0.8	5.7	5.7	5.7	0
Horse 28	7.7	6.3	7.0	1.4	6.7	5.4	6.1	1.3
Horse 29	7.1	7.0	7.1	0.1	7.5	7.2	7.4	0.3
Mean	**6.2**	**5.8**	**6.0**	**0.8**	**5.8**	**5.5**	**5.7**	**0.7**
Standard deviation	**1.1**	**1.0**	**0.9**		**1.0**	**1.2**	**1.0**	
Standard error	**0.2**	**0.2**	**0.2**		**0.2**	**0.2**	**0.2**	
Median	**6.3**	**5.9**	**6.2**		**5.8**	**5.4**	**5.8**	
Confidence interval (95%)	**0.4**	**0.4**	**0.3**		**0.4**	**0.4**	**0.4**	
Upper CI (95%)	**6.6**	**6.2**	**6.4**		**6.2**	**5.9**	**6.0**	
Lower CI (95%)	**5.8**	**5.5**	**5.7**		**5.4**	**5.0**	**5.3**	

Table 5.5.1: ST values for the two muscle groups used in the full trial in backing up ('back') and walking forward ('walk'). Red numbers indicate values below 5.1 which is the upper border for hypermobility in this study. Horses marked with red are the ones assessed as being hypermobile.



Graph 5.5.1: The difference between ST values for two muscle groups, ulnaris lateralis and extensor carpi radialis ('backing up' + 'walk'), for the horses assessed as being hypermobile and borderline. Green area = non-hypermobile ≥5.9. Yellow area = borderline 5.2-5.8. Green area = hypermobile ≤5.1.



Graph 5.5.2: The difference between the ulnaris lateralis and extensor carpi radialis when backing up ('backing up') and walking ('walk'), and the mean for the 29 horses in the full trial, and the standard deviation.

In 'walk', the *ulnaris lateralis* and *extensor carpi radialis* were compared, and 28% (n=8) of the 29 horses had a higher ST value for the *extensor carpi radialis*. Dividing the horses into borderline (n=7) and hypermobile (n=5) assessed, the borderline horses used their *extensor carpi radialis* more in 29% (n=2) of the horses, and the in hypermobile group 20% (n=1) used their *extensor carpi radialis* more than the *ulnaris lateralis*. This gives an indication that the ratio of muscle activity between the *ulnaris lateralis* and *extensor carpi radialis* does not show hypermobility or not, given that the HM scores are reliable.

To compare with the data from the study by Jørgensen (2022), the breeds were divided into types: Warmblood, iberian horses (IB), Icelandic horses, pony (including welsh cobs ≥148) and others (mustang and arabian blend). The distribution can be seen in table 5.5.2.

Keep in mind that as the 29 horses were split into 11 different breeds with 1-8 horses in each breed, a statistical analysis will not be reliable as the number of horses is too low, but it can give some indications to where future studies should focus.

5.5.1 The warmbloods

In the study by Jørgensen (2022), the physiotherapists found that 30% of the warmblood horses examined by them were assessed as being 'whole body' hypermobile, which is defined as being naturally hypermobile, or just referred to as hypermobile in this master thesis study. The study by Jørgensen (2022) showed that the physiotherapists assessed 44% of the warmbloods as being non-hypermobile. Comparing to the warmblood group (n=10) in this study where 30% (n=3) were assessed as hypermobile, 20% (n=2) as borderline and 50% (n=5) as non-hypermobile, the data confirm each other, giving a possible distribution of hypermobility in warmblood horses.

Of the warmblood horses, three (60%, horses 16, 18 and 19) of the five assessed as being non-hypermobile were bred and used for jumping and were related to each other. Horse 17 was from the same breeding and related to the others, this horse was assessed as being hypermobile with a HM score of 4.9, see graph 5.5.1. However, the owner of the horse informed that the horse had an injury, and was possibly lame. If the horse was compensating or sore on the left front limb, the muscles may have been overworked, and not able to restore properly. Horse 17 had an increased difference between the *ulnaris lateralis* and *extensor carpi radialis*, see graph 5.1.1, indicating an injury instead of hypermobility.

5.5.2 The Icelandic horse

In this study, 67% (n=4) of the Icelandic horses were assessed as being non-hypermobile, 17% (n=1) as being hypermobile and 17% (n=1) as being borderline. This was not seen in the study by Jørgensen (2022), where physiotherapists assessed 7% as being non-hypermobile and 54% as being 'whole body' hypermobile, the equivalent to hypermobile.

The study by Jørgensen (2022) suggested that Icelandic horses may have a wider range of motion in their joints, without being hypermobile. As the Icelandic horse is a breed from Iceland where the terrain is rough, with cliffs, stones and ice making the surface uneven, it is not unlikely to think that a wider range in the joints is an advantage. The rough terrain is also said to be the reason for the Icelandic horse's two extra gaits, tölt and flying pace. The Icelandic riding competitions, where tölt and flying pace is pursued, encouraged the breeders to breed animals with large and extravagant movements, making the next generation more prone to hypermobility.

The statistical data from the study by Jørgensen (2022) consist of data collected from physiotherapists when they examine a horse. These horses, however, are not representable of the Danish horse population, as these horses represent those examined by a physiotherapist because the

owner of the horse is having problems. For the Icelandic horse, 82% (32 out of 39) of the horses with ‘problems’ as reason for the physiotherapist to visit were assessed as being ‘whole body’ hypermobile, while 39% (7 out of 18) of the horses with ‘checkup’ as a reason were assessed as ‘whole body’ hypermobile. This means that hypermobility could be overrepresented in the population of Icelandic horses examined by physiotherapists and may not represent the whole Danish population.

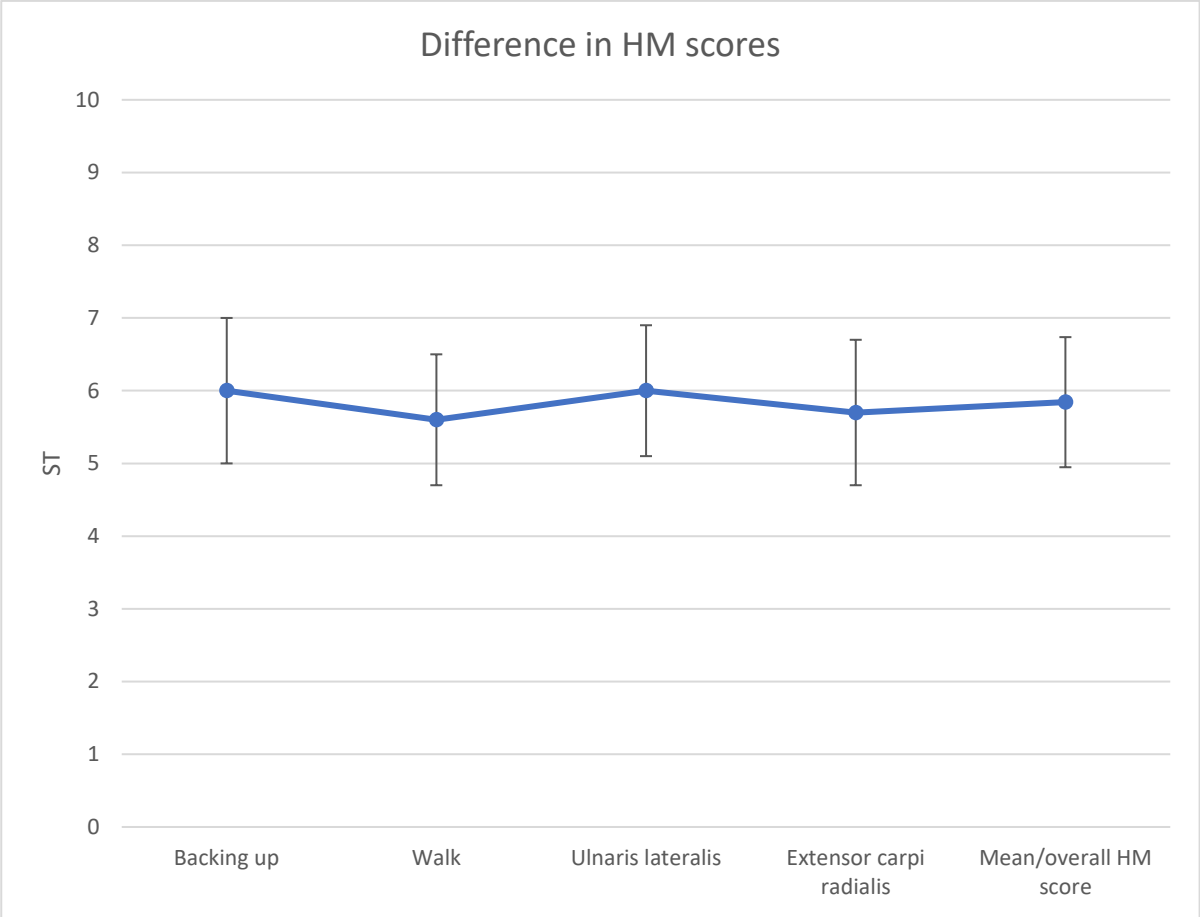
It was also suggested in the study by Jørgensen (2022) that a wider range of joint movement, without being hypermobile, may be perceived as hypermobility, as it is not possible for the physiotherapist to recognize the difference between a highly flexible joint still stabilized and supported by ligaments and one who is not and thereby assessed as being hypermobile. This could be the reason for the difference in the cases of hypermobility, 54% in Jørgensen (2022) and 17% in this study.

Type	Total	Hypermobile		Borderline		Non-hypermobile		Breeds
	n	n	%	n	%	n	%	
Warmblood	10	3	30%	2	20%	5	50%	DV, PRE/warmblood, warmblood blend
IB	7	0	0%	2	29%	5	71%	Lusitano, PRE, PRE/warmblood blend
Icelandic horse	6	1	17%	1	17%	4	67%	Icelandic horses
Pony	4	2	50%	1	25%	1	25%	New forest, welsh, welsh blend
Others	3	0	0%	1	33%	2	67%	Mustang, arabian blend

Table 5.5.2: Type distribution of the 29 horses in the study. PRE/warmblood is represented twice, both in ‘warmblood’ and in ’PRE’, only 1 horse was of this mix.

HM scores					
	Backing up	Walk	*Ulnaris lateralis*	*Extensor carpi radialis*	Mean/overall HM score
Horse 1	5.7	5.8	5.4	6.2	5.8
Horse 2	5.5	4.9	5.4	5.0	5.2
Horse 3	5.0	3.8	4.5	4.3	4.4
Horse 4	7.2	5.9	7.2	5.8	6.5
Horse 5	5.2	4.8	5.6	4.3	5.0
Horse 6	5.6	6.8	6.0	6.4	6.2
Horse 7	5.9	5.7	5.2	6.4	5.8
Horse 8	5.2	6.3	5.6	5.8	5.7
Horse 9	7.0	5.6	6.2	6.5	6.3
Horse 10	6.3	6.2	6.7	5.8	6.2
Horse 11	6.7	7.0	6.9	6.8	6.8
Horse 12	5.9	5.3	5.9	5.3	5.6
Horse 13	7.6	6.4	7.2	6.8	7.0
Horse 14	8.0	7.4	7.6	7.7	7.7
Horse 15	5.8	6.4	6.8	5.4	6.1
Horse 16	6.3	5.5	6.4	5.4	5.9
Horse 17	5.2	4.8	6.0	4.0	5.0
Horse 18	6.3	6.0	6.8	5.5	6.2
Horse 19	6.1	6.6	6.5	6.2	6.3
Horse 20	6.8	5.6	6.6	5.8	6.2
Horse 21	4.0	3.9	4.3	3.6	4.0
Horse 22	5.2	5.1	5.6	4.7	5.1
Horse 23	4.2	4.3	4.4	4.0	4.2
Horse 24	5.8	4.7	5.4	5.1	5.2
Horse 25	7.2	6.3	6.5	7.0	6.7
Horse 26	5.3	4.5	4.4	5.4	4.9
Horse 27	6.3	5.9	6.5	5.7	6.1
Horse 28	7.2	5.9	7.0	6.1	6.5
Horse 29	7.3	7.1	7.1	7.4	7.2
Mean	6.0	5.6	6.0	5.7	5.8
Upper limit for hypermobility	5.3	4.7	5.2	4.8	5.1
Standard deviation	1.0	0.9	0.9	1	0.9

Table 5.5.3: The individual HM scores for the two muscle groups and the two moving phases, as well as the overall mean or HM score for 29 horses in the full trial, with their own upper limit for hypermobility and standard deviations. Values marked with red are values under the upper limit for hypermobility in the specific group. The 'upper limit for hypermobility' is the mean of the horses with HM scores below the mean of the group.



Graph 5.5.4: Differences in the mean HM scores between the muscles groups and moving phases used in the full trail, with the standard deviations.

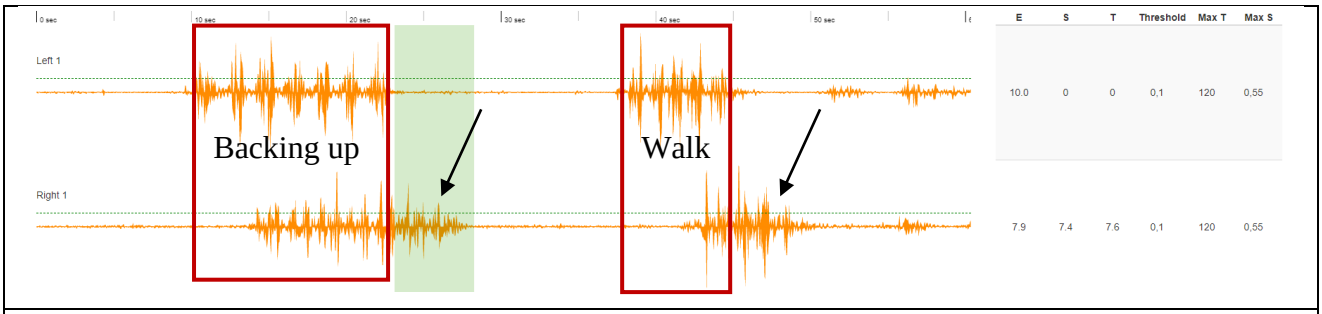
5.6 Other observations: Biceps femoris in horse 3

The measurements from horse 3's *biceps femoris* and *gluteus medius* showed that after a moving phase, the *biceps femoris* was active for a few seconds, see picture 5.6.1. This horse had a HM score of 4.3, being assessed as hypermobile, and having one of the lowest HM scores of all the test subjects. The *biceps femoris* being active after the horse has stopped moving, may be an indication of the muscle stabilizing the horse's hindquarters due to its hypermobile state.

None of the other horses from the preliminary trial (horses 1, 2, 4 and 5) showed this, but none of them had as low an HM score as horse 3. It could be that hypermobility in more severe cases decrease the joint's stability to such a degree, that the horse's myofascial kinetic lines are not enough to stabilize the body, thereby putting more strain on the muscles because the horse is relying on the muscles to stabilize the body and the individual joints. This could be an indication of true

hypermobility or more severe hypermobility, where the muscles have an increased activity in transitions between gaits, especially when the horse returns to a standstill after moving.

Measuring the *gluteus medius* and *biceps femoris* at the same time, on horses with HM score under 5.1, could lead to a better understanding of what is happening.



Picture 5.6.1.: The measurement at 21 dB gain from horse 3. The top-line measuring is the gluteus medius, and the bottom-line measuring is the biceps femoris, both on the left side of the horse. The measurements show that gluteus medius is active in the horse's moving phase ('backing up' and 'walk', red squares), and the biceps femoris remains active a few seconds after the horse has stopped moving (black arrows).

6. Discussion

Some of the data in this study may indicate muscle compensation not due to hypermobility, as some of the horses have increased differences between left and right side, and between the muscle groups. Looking at the individual ST means from the different muscle groups and left and right side, not all horses are clear in one area of the hypermobility assessment. Some horses are assessed at being borderline in one muscle group and hypermobile in another, see graph 5.5.1.

There are other topics to be discussed as some horses show different results than expected, and there are some variables that need to be considered.

6.1 Injuries

Injuries could affect the measurements in different ways. When injured or lame, the horse can compensate throughout the body to reduce structural stress (Weishaupt, Weistner, Hogg, Jordan, & Auer, 2006). Taking the load off some muscle groups and increasing the workload for others will influence the reliability to use AMG to hypermobility assessment, as this could mean that an injured muscle could be measured with a high ST value (low muscle activity) and the non-injure muscle with a low ST value (high muscle activity). If only the compensating muscle group

was to be measured, the horse could get a HM score in the hypermobile area, without being hypermobile.

Longer periods of injury or pain could result in an overall tension throughout the horse's body, decreasing the muscle's ability to restore. Knowing the pattern of muscle activity between the muscle groups normally seen, as graph 5.1.1 indicates, may give important information as a diagnostic tool. The ST scores can show a deviation in the pattern, and may indicate the different way the muscles are used when compensating. Further study is suggested to find a reliable way of distinguishing between an injured horse and a hypermobile one.

6.2 What we see vs. AMG

In this study, the Icelandic horses all came from the same stable, the owner of the stable told that they expected horses 27 and 29 to be hypermobile, as they seemed very flexible in their movement. Both horses were assessed in this study to be non-hypermobile with HM scores 6.2 (horse 27) and 7.2 (horse 29). This could be an indication of the Icelandic horse having a wider range in its movement with the ligaments not losing their supportive role and overstraining the muscles. This could also mean that using AMG on the *extensor carpi radialis* and *ulnaris lateralis* and creating a HM score through the average of these measurements is not a reliable way of assessing hypermobility. However, the study by Jørgensen (2022) showed that the subjective assessment from palpating a joint, is unreliable, and it is possible that assessing hypermobility by looking at the horse's movement may prove to be too subjective as well.

There is also the variable of training, as all the Icelandic horses came from the same stable, specialized in training Icelandic horses and focusing on the durability of the horses. With the right training, hypermobility may not strain the muscles as much, resulting in a higher HM score. How training can affect the HM scores needs to be studied further, to see if the score can be influenced or if they remain stable.

6.3 Measuring conditions

All measurements were done in the winter months, with all the horses having their winter coats. This could possibly cause problems for the sensors used in this study, even when using acoustic gel, as air is trapped under fur of the horse making the horse able to regulate its body temperature. Air can increase the impedance at the skin/air interface (Harrison, 2018), obscuring the sound waves from the muscles.

Doing the measurement in the winter, where the weather is wet and cold proved to give some problems with the Bluetooth connection. The internet connection was not always reliable and some of the data was lost.

Measuring in the summer period, when the horses have a thinner coat, and the weather is dry and warmer, could improve the measuring conditions. A stable and reliable internet connection is also preferable, but as most horses are stabled in the countryside, this could be more difficult to improve on.

6.4 Biased observations

Choosing the five second area on the AMG measuring results is not objective, but subjective, as a moving phase (‘backing up’ or ‘walk’) often lasts for more than five seconds, and the most representable 5 second area needs to be chosen. Finding an area with clear S and T values is sometimes difficult, and the process could be biased. If the horse were Icelandic, there could be a presumption that this horse is hypermobile, accepting lower S and T scores instead of looking for higher values.

The fear of being biased could also pose a problem, as the search for higher S and T values may be exaggerated and the S and T values may not be representable.

Often the highest S and T value for the two muscle groups measured at the same time were found and used, making sure that the S and T values were the highest readable for each horse.

To make sure that the bias is decreased, it would be suggested that the whole walking phase is used, and not just a 5 second cut, provided that the whole walk is calm and smooth.

6.5 Different ways of compensating

Horses could have different ways of compensating, using different muscles to compensate when hypermobile. This could mean that hypermobility could manifest in different ways when the horse is moving. As horses are trained and ridden, there could also be a difference between a trained and untrained horse, as the trained horse has learned to use its body differently.

A hypermobile horse may need training focused on increasing strength and proprioception, as the muscles are overworked. If the training needs are not met, it could result in sore muscles or injuries, making it harder to distinguish between hypermobility and injuries.

It could be that hypermobility can manifest in different ways and thereby different problems, because the body can cope or compensate in different ways depending on the horse, and on the severeness of the hypermobility and maybe earlier injuries or trauma. This could mean that the problems the horses and owners are having can be very different.

Hypermobility is difficult to assess in horses, as there are many variables. The only way to be sure if the assessment and diagnostic tool is correct, is by taking a sample of the horse's ligaments, and looking at the ligament structure. However, using AMG can give important information about possible injuries, possible hypermobility, and fitness conditions of a horse.

7. Conclusion

Acoustic Myography (AMG) may be a reliable way of assessing hypermobility in horses. Measuring the muscles *extensor carpi radialis* and *ulnaris lateralis* may give an indication of the horse's hypermobility status through an HM score calculated from the mean of the measurements in a moving phase. Walking forward ('walk') is representable and may give the indications needed to assess hypermobility through the HM score as a diagnostic tool when using the AMG. The HM scores calculated in this study is based on both 'walk' and 'backing up'.

It may be possible to determine hypermobility through measurements of muscle activity, when measuring at least two different muscle groups. It can be difficult to distinguish between hypermobility and local muscle compensation due to other causes. Measuring both the *ulnaris lateralis* and the *extensor carpi radialis* and the difference between them, could indicate if the horse is hypermobile or injured. As a single muscle group, *ulnaris lateralis* seem to be the most reliable, however, both the left and right side needs to be measured. Hypermobility cannot be assessed in a reliable way using only one muscle.

Measuring the *gluteus medius* and *biceps femoris* could be a reliable tool when assessing hypermobility, as the *gluteus medius* may compensate for the *biceps femoris* in moving phases. It is suggested that this should be studied further by measuring the *gluteus medius* and *biceps femoris* on horses assessed as being hypermobile through the HM score tool.

8. Perspective

A general hypermobility database should be available for breeders, buyers, and professionals such as veterinarians. As hypermobility is an overlooked area that could have a big impact on horse welfare, it is suggested that horses should be assessed as part of their performance testing at stallion and mare shows. At these shows, judges assess the visual appearance, the rideability and jumping ability of a horse. A veterinarian check including a hypermobility assessment using AMG should be included. Acoustic myography has proven to be a quick, easy and non-invasive way to do measurements on the muscles, and would be an important tool.

A horse needs to be measured on at least two muscle groups. Based on the findings from this master thesis, it is suggested to measure the left side, as the left side is used in this study, *ulnaris lateralis* and *extensor carpi radialis*, or both the left and right side *ulnaris lateralis* and *extensor carpi radialis*. With more horses and data included in a hypermobility database, other muscle combinations may be found more suitable for the hypermobility assessment. When measuring, the horse should walk a straight line of 40m on a flat soft surface, like in a riding arena. The horse should be calm and be walked at a smooth, even pace. This will ensure a longer measuring period. The S and T values should be obtained through a cut five seconds after the movement has started and five seconds before it has ended, see graph 8.1, ending up with a repeatable measuring. This will take account for the acceleration and deceleration phases. All five amplitudes (18-, 21-, 24-, 27- and 32 dB gain) should be used. Using this method a new HM score needs to be calculated, and the borderlines from table 4.2.1 needs to be adjusted.

It is recommended that the software used for the AMG data collection is updated so the switch between the different amplitudes is shown in the graph created. It would also be a good idea to be able to pause the measuring, if the horse needs to be corrected, as this can create an area in the graph were the data is not valid, and it can be difficult to see and remember this an account for it when looking at the data.

Horses in breeding and sports should be measured at three years of age, those assessed as being hypermobile should be assessed again when considered fully grown by breed standards.

Having a horse hypermobility assessed will give important information, impacting the horse’s future in sports and breeding. It could give valuable information to a horse owner on how

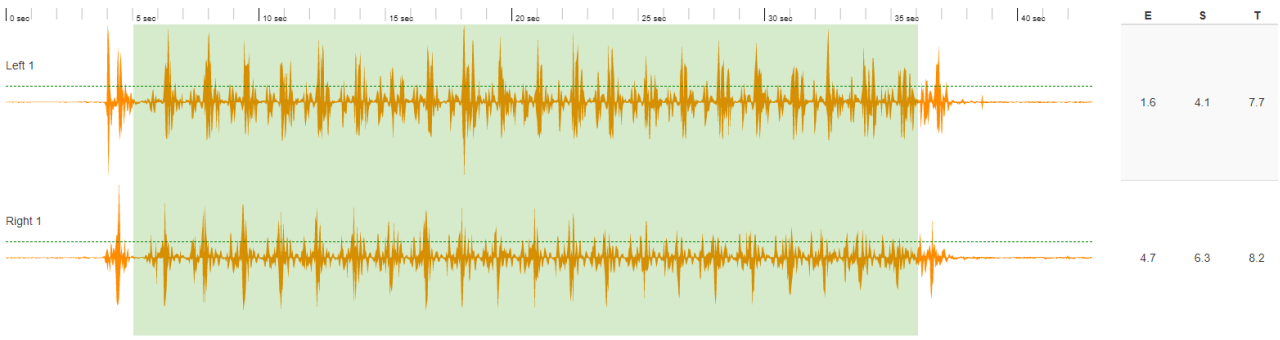
the horse needs to be handled to insure its welfare and performance. It could also be an important tool for veterinarians, when trying to diagnose a lame horse with no clear injury.

Having a hypermobility database may also provide some clarity on the horse's durability, if injuries are more common in the hypermobile horse, and breeders may choose non-hypermobile horses for their next generation. A hypermobility database could also give some clarity on the injuries horses with hypermobility may suffer from, and how they perform as athletes.

Further studies on the area should be done, and it is suggested that *biceps femoris* and *gluteus medius* should be included, as horse 5 showed some interesting results on these muscles. If increased activity in the *biceps femoris* after an end moving phase is seen only in hypermobile horses, then this could be a simple way of assessing hypermobility through only on muscle group.

AMG as a diagnostic tool can be used by veterinarians and other professionals with similar knowledge of the horse's locomotive system, as locating the correct muscles to measure is crucial. Veterinarians should include this tool when examining a lame horse or doing health evaluations for buyers and insurance companies.

Knowing more about hypermobility could contribute to the welfare of horses.



Graph 8.1: Measurement in 18 dB gain of the extensor carpi radialis (bottom) and ulnaris lateralis (top) in walk. The green area indicates the area of which the S and T values were found, starting five secund after the moving phase has started and stops five seconds before the moving phase has ended.

References

Grahame, R. (1999). Joint hypermobility and genetic collagen disorders: are they related? *Arch Dis Child, 80,* pp. 188-191.

Hakim, A., & Grahame, R. (2003). Joint hypermobility. *Best practice & research. Clinical rheumatology. [Online] 17 (6),* pp. 989-1004.

Hall, M. G., Ferrel, W. R., Sturrock, R. D., Hamblen, D. L., & Baxendale, R. H. (1995). THE EFFECT OF THE HYPERMOBILITY SYNDROME ON KNEE JOINT PROPRIOCEPTION. *Rheumatology, Volume 34*, pp. 121-125.

Hardy, M., Fisher, K., Vrablic, O. E., Nimmo-Wilkie, J., Parker, W., & Keeley, F. (1988, 08 01). An inherited connective tissue disease in the horse. *Laboratory Investigation; a journal of Technical Methods and Pathology*, pp. 253-262.

Harrison, A. P. (2018). A more precise, repeatable and diagnostic alternative to surface electromyography – an appraisal of the clinical utility of acoustic myography. *Clinical Physiology and Functional Imaging, 38 (2),* pp. 312-325.

Jørgensen, M. L. (2022). *Hypermobility in Horses.* University of Copenhagen.

McElroy, A., Rashmie, A., Manfredi, J., Sledge, D., Carr, E., Stopa, E., & Klinge, P. (n.d.). Evaluation of the Structure of Myodural Bridges in an Equine Model of Ehler-Danlos Syndromes.

MSK expert panel. (2022, December 05). *NHS inform*. Retrieved from https://www.nhsinform.scot/illnesses-and-conditions/muscle-bone-and-joints/conditions/joint-hypermobility#treating-joint-hypermobility

Pyeritz, R. E. (2000). Ehlers–Danlos Syndrome. *The New England Journal of Medicine*, pp. 730-732.

Schultz, N. (2021). *Hereditary equine regional dermal asthenia (HERDA)*. Retrieved from University Of Minnesota Extension: https://extension.umn.edu/horse-health/hereditary-equine-regional-dermal-asthenia-herda

Schultz, R. M., Due, T., & Elbrønd, V. S. (2021). *Equine Myofascial Kinetic Line - for professionals.* Mørkøv: Fascialine.com Aps.

Smith, T. O., Jerman, E., Easton, V., Bacon, H., Armon, K., Poland, F., & Mcgregor, A. J. (2013). Do people with benign joint hypermobility syndrome (BJHS) have reduced joint proprioception? A systematic review and meta-analysis. *Rheumatology International volume 33*, pp. 2709-2716.

Søborg, M.-L. K., Leganger, J., Mortensen, L. Q., Burcharth, J., & Rosenberg, J. (2017). Establishment and baseline characteristics of a nationwide Danish cohort of patients with Ehlers–Danlos syndrome. *Rheumatology, Volume 56, Issue 5*, pp. 763-767.

Tuthill, J. C., & Azim, E. (2018, 03 05). Proprioception. *Current Biology, 28*.

Vitger, A. D., Bruhn-Rasmussen, T., Pedersen, E. O., Fuglsang-Damgaard, L. H., & Harrison, A. P. (2021). The impact of water depth and speed on muscle fiber activation of healthy dogs walking in a water treadmill. *Acta Veterinarian Scandinavica*.

Weishaupt, M. A., Weistner, T., Hogg, P. H., Jordan, P., & Auer, J. A. (2006). Compensatory load redstribution of horses with induced weight-bearing forelimb lameness trotting on a treadmill. *The Veterinary Journal 171*, pp. 135-146.

Appendix

Appendix 1 – Detail on the horses

Horse	Breed	Age. years	Height/expected height. cm	Usage	ST mean	Gender
1	PRE	17	165	Dressage	5.7	Gelding
2	PRE	2	160	All round	5.2	Mare
3	Welsh Cob	5	148	All round	4.3	Mare
4	Welsh Cob	3	150	All round	6.5	Gelding
5	New Forest	13	155	Western	5.0	Gelding
6	Arab blend	22	147	Pleasure	6.2	Mare
7	Arab blend	8	153	Pleasure	5.7	Mare
8	Welsh blend	19	148	All round	5.7	Gelding
9	PRE	7	162	All round	6.3	Gelding
10	PRE	8	162	All round	6.3	Gelding
11	PRE/warm blood	2	164	All round	6.8	Mare
12	Warm blood blend	9	166	All round	5.5	Mare
13	PRE	2	158	All round	7.0	Gelding
14	Mustang	3	150	All round	7.7	Gelding
15	Lusitano	17	165	All round	6.1	Gelding
16	DV	8	177	Jumping	5.9	Mare
17	DV	7	178	Jumping	4.9	Gelding
18	DV	3	174	Jumping	6.2	Mare
19	DV	20	175	Jumping	6.3	Mare
20	DV	20	167	Allround	6.1	Gelding
21	DV	12	162	Allround	4.0	Gelding
22	DV	18	165	Allround	5.2	Mare
23	DV	16	167	Allround	4.1	Mare
24	Icelandic horse	15	145	Pleasure	5.2	Mare
25	Icelandic horse	7	144	Icelandic comp.	6.7	Gelding
26	Icelandic horse	10	138	Icelandic comp.	4.9	Mare
27	Icelandic horse	16	136	Pleasure	6.2	Mare
28	Icelandic horse	10	139	Icelandic comp.	6.6	Gelding
29	Icelandic horse	11	137	Icelandic comp.	7.2	Gelding

Appendix 2 – Results horse 1-5

Horse 1

Horse 1 5 sec cut

Left side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	3.5	7.0	4.8	9.7	3.4	7.4	2.5	8.0	5.1	7.1
Stand Walk	5.3	8.9	4.6	8.0	1.2	5.7	0.3	2.2	5.1	8.6
Stand Back up	6.1	9.2	5.5	8.4	3.5	8.2		5.8	5.6	8.3
Stand Walk Stand	6.3	9.1	2.9	6.0	0.5	6.3	1.2	5.1	5.4	8.0
	5.3	8.6	4.5	8.0	2.2	6.9	1.3	5.3	5.3	8.0

ST mean	6.9	6.2	4.5	3.3	6.7

Right side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	5.1	8.3	2.7	6.7	4.6	7.9	1.9	6.2		5.5
Stand Walk	5.4	8.7	3.5	7.7	4.1	8.5		5.1	5.5	8.1
Stand Back up	4.4	7.3	2.8	7.5	1.9	7.4	3.6	7.2	2.0	7.1
Stand Walk Stand	5.1	8.5	5.4	8.2	3.9	8.0		5.9	5.1	9.1
	5.0	8.2	3.6	7.5	3.6	8.0	2.8	6.1	4.2	7.5

ST mean	6.6	5.6	5.8	4.4	5.8

5 sec cut

Left side *Extensor carpi radialis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	7.1	9.8	6.3	8.7	5.9	7.6	2.9	7.2	7.5	9.3
Stand Walk	6.1	8.9	5.8	8.5	5.2	7.3	2.5	7.9	6.7	9.0
Stand Back up	6.9	10.0	6.0	7.9	4.8	7.7	2.4	4.2	6.6	9.3
Stand Walk Stand	6.3	9.3	5.6	8.5	4.5	7.7	2.6	6.0	6.2	8.7
	6.6	9.5	5.9	8.4	5.1	7.6	2.6	6.3	6.8	9.1

ST mean	8.1	7.2	6.3	4.5	7.9

Right side *Extensor carpi radialis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	6.0	8.4	4.5	7.7	3.8	7.4		6.2	5.7	8.9
Stand Walk	7.2	9.5	6.7	8.4	5.2	7.2	2.3	6.0	6.7	9.4
Stand Back up	2.0	7.8	2.6	7.0		6.2	2.2	6.9	6.0	9.4
Stand Walk Stand	6.9	9.7	4.8	8.3	4.5	7.9	2.7	6.0	7.4	9.3
	5.5	8.9	4.7	7.9	4.5	7.2	2.4	6.3	6.5	9.3

ST mean	7.2	6.3	5.8	4.3	7.9

5 sec cut

Left side *Gluteus medius*

dB	**18**		**21**		**24**		**27**			
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**		
Stand Back up	7.8	10.0	6.5	6.3	6.8	8.2	7.0	8.3		
Stand Walk Stand	7.2	3.1	7.5	7.4	7.4	7.6	7.2	9.9		
	7.5	6.6	7.0	6.9	7.1	7.9	7.1	9.1	0.0	0.0

ST mean	7.0	6.9	7.5	8.1	0.0

Left side *Biceps femoris*

dB	**18**		**21**		**24**		**27**			
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**		
Stand Back up	6.3	8.7	3.0	6.1	4.8	5.6	5.1	8.4		
Stand Walk Stand	7.0	8.8	6.5	6.4	6.2	7.8	4.4	8.9		
	6.7	8.8	4.8	6.3	5.5	6.7	4.8	8.7		

ST mean	7.7	5.5	6.1	6.7	0.0

Horse 2

Horse 2 5 sec cut

Left side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	0.3	6.5	2.9	6.6		5.0	2.9	5.7		
Stand										
Walk	4.0	8.4		6.1	2.6	7.9		5.7		
Stand										
Back up					4.2	8.6	4.8	7.6	2.9	7.4
Stand										
Walk					6.1	8.5	5.0	7.9	2.6	6.6
Stand										
	2.2	7.5	2.9	6.4	4.3	7.5	4.2	6.7	2.8	7.0
ST mean		4.8		4.6		5.9		5.5		4.9

Right side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	5.2	8.7	3.1	7.6		4.9	4.3	8.2		
Stand										
Walk	6.3	9.2	3.0	7.5	2.7	7.6	1.2	7.1		
Stand										
Back up					3.4	8.0	2.1	7.1	0.8	5.9
Stand										
Walk					5.0	6.2	5.1	5.3	2.0	2.8
Stand										
	5.8	9.0	3.1	7.6	3.7	6.7	3.2	6.9	1.4	4.4
ST mean		7.4		5.3		5.2		5.1		2.9

5 sec cut

Left side *Extensor Carpi Radialis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	7.0	8.4	5.8	8.8	5.7	8.6	4.2	8.5	1.4	7.0
Stand Walk	4.7	8.0	4.4	7.5	4.4	7.5	1.7	6.1		3.7
	5.9	8.2	5.1	8.2	5.1	8.1	3.0	7.3	1.4	5.4

ST mean	7.0	6.6	6.6	5.1	3.4

Right side *Extensor Carpi Radialis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	5.5	8.1	4.8	7.0	4.8	7.0	2.8	3.0	1.5	5.0
Stand Walk	5.7	8.3	3.1	6.3	3.1	6.3	1.5	0.2		1.6
	5.6	8.2	4.0	6.7	4.0	6.7	2.2	1.6	1.5	3.3

ST mean	6.9	5.3	5.3	1.9	2.4

5 sec cut

Left side *Gluteus medius*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up			6.9	9.2	7.8	10.0	6.7	8.4	5.3	8.8
Stand Walk							6.9	9.5	6.4	9.6
	####	####	6.9	9.2	7.8	10.0	6.8	9.0	5.9	9.2

ST mean	####	8.1	8.9	7.9	7.5

Left *Biceps femoris*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up			4.4	7.9	5.7	7.8	4.2	7.0	2.6	4.4
Stand Walk			5.3	8.3	4.9	7.3	2.9	7.8	1.6	5.8
	####	####	4.9	8.1	5.3	7.6	3.6	7.4	2.1	5.1

ST mean	####	6.5	6.4	5.5	3.6

Horse 3

Horse 3 5 sec cut

Left side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	5.0	7.6	4.6	6.9	1.1	6.3		5.3		
Stand Walk	5.8	7.4	2.4	6.6	2.7	4.5	1.4	3.8		
	5.4	7.5	3.5	6.8	1.9	5.4	1.4	4.6	####	####

ST mean	6.5	5.1	3.7	3.0	####

Right side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	6.4	8.5	3.1	5.9	1.3	3.2	1.7	5.6		
Stand Walk	5.4	7.5	2.9	5.8	0.7	3.8	0.4	4.2		
	5.9	8.0	3.0	5.9	1.0	3.5	1.1	4.9	####	####

ST mean	7.0	4.4	2.3	3.0	####

5 sec cut

Left side *Extentsor carpi radialis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	4.2	6.5	3.2	6.9		3.5		3.2		
Stand										
Walk	1.2	5.1	0.0	1.8		3.3		2.1		
Stand										
	2.7	5.8	1.6	4.4		3.4		2.7		

ST mean	4.3	3.0	3.4	2.7	0.0

Right side *Extentsor carpi radialis*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	6.7	9.5	5.7	7.2	3.7	7.5	3.7	7.5		
Stand										
Walk	5.3	8.8	1.9	8.7	2.0	7.3	1.2	6.7		
Stand										
	6.0	9.2	3.8	8.0	2.9	7.4	2.5	7.1	####	####

ST mean	7.6	5.9	5.1	4.8	####

5 sec cut

Left side *Gluteus medius*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	7.5	7.3	3.3	2.2	6.1	8.1	2.7	6.2		
Stand										
Walk	7.5	9.9	2.9	2.8	5.1	6.6	4.6	7.8		
Stand										
	7.5	8.6	3.1	2.5	5.6	7.4	3.7	7.0	####	####

ST mean	8.1	2.8	6.5	5.3	####

Left side *Biceps femoris*

dB	**18**		**21**		**24**		**27**		**18**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up			7.3	6.0	7.6	7.4	6.8	9.8		
Stand										
Walk			4.8	6.2	6.3	8.1	7.0	7.9		
Stand										
	####	####	6.1	6.1	7.0	7.8	6.9	8.9	####	####

ST mean	####	6.1	7.4	7.9	####

Horse 4

Horse 4 5 sec cut

Left side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	7.6	9.6	7.5	10.0	7.1	8.9	5.4	8.6	5.3	9.1
Stand Walk	4.0	9.2	4.1	8.9	4.1	8.0	2.2	7.5	3.7	8.2
	5.8	9.4	5.8	9.5	5.6	8.5	3.8	8.1	4.5	8.7
ST mean		7.6		7.6		7.0		5.9		6.6

Right side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	7.9	9.2	7.6	9.8	6.0	8.3	6.2	7.3	6.6	8.5
Stand Walk	6.6	8.8	7.3	9.5	5.6	9.5	5.5	8.7	2.1	6.7
	7.3	9.0	7.5	9.7	3.9	4.5	2.9	4.0	4.4	7.6
ST mean		8.1		8.6		4.2		3.5		6.0

5 sec cut

Left side *Extensor Carpi Radialis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	6.4	8.7	6.0	9.1	3.5	8.2	4.3	7.9	3.0	8.3
Stand Walk	5.9	9.0	5.0	6.4	3.1	8.0	1.8	8.0	2.1	7.6
	6.2	8.9	5.5	7.8	3.3	8.1	3.1	8.0	2.6	8.0

ST mean	7.5	6.6	5.7	5.5	5.3

Right side *Extensor Carpis Radialis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	4.8	8.7	5.4	7.1	5.0	7.4	3.5	8.0	5.0	6.5
Stand Walk	5.4	9.1	3.5	7.0	1.0	5.4	2.0	5.9	1.9	5.1
	5.1	8.9	4.5	7.1	3.0	6.4	2.8	7.0	3.5	5.8

ST mean	7.0	5.8	4.7	4.9	4.6

5 sec cut

Left side *Gluteus medius*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up					7.3	9.7	6.6	8.6	7.6	9.7
Stand Walk							7.8	9.2	7.9	10.0
	####	####	####	####	7.3	9.7	7.2	8.9	7.8	9.9
ST mean		####		####		8.5		8.1		8.8

Left *Biceps femoris*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	7.5	9.5	7.2	8.8	5.5	6.9	4.2	6.9	4.1	6.4
Stand Walk	7.3	9.0	7.0	8.7	6.1	8.3	4.8	8.0	4.2	7.7
	7.4	9.3	7.1	8.8	5.8	7.6	4.5	7.5	4.2	7.1
ST mean		8.3		7.9		6.7		6.0		5.6

Horse 5

Horse 5 5 sec cut

Left side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	6.2	9.0	4.3	5.9	4.8	6.1	4.4	5.7	0.5	6.2
Stand Walk	5.7	8.3	5.1	7.9	3.1	6.2	2.3	4.9	0.5	2.5
	6.0	8.7	4.7	6.9	4.0	6.2	3.4	5.3	0.5	4.4
ST mean		7.3		5.8		5.1		4.3		2.4

Right side *Ulnaris lateralis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand										
Back up	7.4	9.8	4.8	8.5	7.1	8.8	3.0	7.4	1.0	6.5
Stand Walk	7.0	8.5	6.2	8.3	4.2	7.2	3.7	5.9	1.3	6.1
	7.2	9.2	5.5	8.4	5.7	8.0	3.4	6.7	1.2	6.3
ST mean		8.2		7.0		6.8		5.0		3.7

5 sec cut

Left side *Extensor Carpi Radialis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	3.6	7.5	3.8	6.7	1.0	4.0	0.4	1.6	1.9	5.2
Stand Walk	6.7	7.3	5.4	7.0	2.3	5.2	1.3	2.6	1.2	3.3
	5.2	7.4	4.6	6.9	1.7	4.6	0.9	2.1	1.6	4.3
ST mean		6.3		5.7		3.1		1.5		2.9

Right side *Extensor Carpi Radialis*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	3.6	8.2	5.5	9.1	2.1	7.2	1.3	5.8	3.4	6.2
Stand Walk	5.7	7.5	2.0	6.0	2.2	6.2	0.5	4.1	1.8	5.0
	4.7	7.9	3.8	7.6	2.2	6.7	0.9	5.0	2.6	5.6
ST mean		6.3		5.7		4.4		2.9		4.1

5 sec cut

Left side *Gluteus medius*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up							6.0	8.3	6.8	9.3
Stand Walk							7.2	9.8	6.3	8.6
	####	####	####	####	####	####	6.6	9.1	6.6	9.0

ST mean		####		####		####		7.8		7.8

Left *Biceps femoris*

dB	**18**		**21**		**24**		**27**		**32**	
	S	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Stand Back up	3.0	8.9	3.0	8.9	3.1	8.2	1.6	6.5	2.2	6.0
Stand Walk	5.8	8.3	5.8	8.3	2.5	8.2	1.2	7.4	3.8	6.5
	4.4	8.6	4.4	8.6	2.8	8.2	1.4	7.0	3.0	6.3

ST mean		6.5		6.5		5.5		4.2		4.6

Appendix 3 – Results horse 6-29

Extensor carpi radialis

Horse 6	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.0	8.5	1.9	7.8	2.9	8.0	3.1	8.6		5.8
	Walk	7.6	9.2	6.8	8.4	6.2	8.3	5.0	8.0	4.1	6.9
	Mean	6.3	8.9	4.4	8.1	4.6	8.2	4.1	8.3	4.1	6.4
	ST mean		7.6		6.2		6.4		6.2		5.2

Horse 7	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.5	9.2	2.8	8.7	3.3	8.9	0.4	8.1		7.6
	Walk	7.4	9.1	5.8	8.8	6.0	8.4	3.5	6.4	3.4	7.0
		6.5	9.2	4.3	8.8	4.7	8.7	2.0	7.3	3.4	7.3
	ST mean		7.8		6.5		6.7		4.6		5.4

Horse 8	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.5	9.2	4.9	8.4	2.8	8.4	1.4	6.3	1.0	6.3
	Walk	5.0	8.5	6.2	8.3	5.9	6.3	4.4	5.9	3.7	7.5
		5.3	8.9	5.6	8.4	4.4	7.4	2.9	6.1	2.4	6.9
	ST mean		7.1		7.0		5.9		4.5		4.6

Horse 9	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.5	9.2	6.6	9.6	5.7	8.8	6.7	8.5	3.6	7.5
	Walk	6.8	9.4	5.5	7.9	3.7	6.7	2.7	5.4	1.6	6.5
		6.7	9.3	6.1	8.8	4.7	7.8	4.7	7.0	2.6	7.0
	ST mean		8.0		7.4		6.2		5.8		4.8

Horse 10	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.3	8.6	4.7	8.4	3.8	7.8	5.9	8.5	2.5	7.8
	Walk	6.3	8.2	3.2	6.6	1.6	6.5	2.7	6.9	3.6	7.5
		5.8	8.4	4.0	7.5	2.7	7.2	4.3	7.7	3.1	7.7
	ST mean		7.1		5.7		4.9		6.0		5.4

Horse 11	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.4	8.6	6.1	9.5	5.1	8.0	4.6	7.3	2.8	5.7
	Walk	7.2	9.6	7.6	7.9	6.3	8.7	5.1	6.7	4.7	6.8
		7.3	9.1	6.9	8.7	5.7	8.4	4.9	7.0	3.8	6.3
	ST mean		8.2		7.8		7.0		5.9		5.0

Horse 12	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.6	9.1	5.4	8.0	3.0	6.3	2.9	6.8	2.5	3.6
	Walk	4.6	7.1	4.3	6.5	1.9	6.3	3.7	7.9	3.8	4.5
		5.6	8.1	4.9	7.3	2.5	6.3	3.3	7.4	3.2	4.1
	ST mean		6.9		6.1		4.4		5.3		3.6

Horse 13	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.1	9.5	6.1	8.1	6.1	9.1	6.5	8.0	3.8	7.5
	Walk	5.0	8.4	6.9	9.2	4.6	9.0	2.6	7.0	2.4	7.3
		6.1	9.0	6.5	8.7	5.4	9.1	4.6	7.5	3.1	7.4
	ST mean		7.5		7.6		7.2		6.0		5.3

Horse 14	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up			5.0	8.2	7.3	9.9	7.4	9.9		
	Walk	7.3	8.9	7.1	8.5	6.9	8.6	4.4	6.9		
		7.3	8.9	6.1	8.4	7.1	9.3	5.9	8.4		
	ST mean		8.1		7.2		8.2		7.2		

Horse 15	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.9	6.7	5.5	8.7	3.9	6.8	2.9	6.4	1.2	3.3
	Walk	5.9	7.7	5.9	8.8	4.5	8.1	2.0	7.6	1.5	5.7
		5.4	7.2	5.7	8.8	4.2	7.5	2.5	7.0	1.4	4.5
	ST mean		6.3		7.2		5.8		4.7		2.9

Horse 16	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.0	9.2	4.0	6.4	3.4	6.5	3.8	5.6	4.6	3.3
	Walk	6.4	8.5	4.9	5.3	3.8	4.4	2.5	2.5	7.8	9.7
		6.2	8.9	4.5	5.9	3.6	5.5	3.2	4.1	6.2	6.5
	ST mean		7.5		5.2		4.5		3.6		6.4

Horse 17	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up			3.3	4.5	4.4	5.6	3.4	5.5		
	Walk			4.3	4.8	2.7	3.4	2.1	1.2		
				3.8	4.7	3.6	4.5	2.8	3.4		
	ST mean				4.2		4.0		3.1		

Horse 18	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.7	8.8	3.2	8.0	4.8	8.5	4.2	4.0	3.0	8.0
	Walk	2.4	8.8	4.3	8.1		4.4	3.6	6.2	3.9	5.6
		4.1	8.8	3.8	8.1	4.8	6.5	3.9	5.1	3.5	6.8
	ST mean		6.4		5.9		5.6		4.5		5.1

Horse 19	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.8	9.1	3.6	8.7	5.4	9.0	2.8	6.3	3.6	6.9
	Walk	5.0	9.0	4.3	8.1	5.0	8.2	5.0	7.1	3.7	6.1
		5.4	9.1	4.0	8.4	5.2	8.6	3.9	6.7	3.7	6.5
	ST mean		7.2		6.2		6.9		5.3		5.1

Horse 20	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.4	8.9	5.6	7.3	5.2	7.8	4.2	5.9	3.7	5.8
	Walk	6.5	9.0	4.7	6.2	1.7	3.5	2.4	6.1	3.2	7.4
		7.0	9.0	5.2	6.8	3.5	5.7	3.3	6.0	3.5	6.6
	ST mean		8.0		6.0		4.6		4.7		5.0

Horse 21	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.1	8.3	2.1	5.8	1.7	4.8	1.6	3.3	2.6	3.5
	Walk	3.4	6.6	2.5	6.0	1.9	3.9	2.3	3.2	2.6	1.7
		3.8	7.5	2.3	5.9	1.8	4.4	2.0	3.3	2.6	2.6
	ST mean		5.6		4.1		3.1		2.6		2.6

Horse 22	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.1	7.9	5.2	7.9	2.0	4.8	2.5	6.3	1.6	2.8
	Walk	4.2	7.2	6.0	8.3	4.0	4.9	1.3	4.1	2.5	6.6
		5.2	7.6	5.6	8.1	3.0	4.9	1.9	5.2	2.1	4.7
	ST mean		6.4		6.9		3.9		3.6		3.4

Horse 23	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.1	6.8	1.8	4.8		5.0	2.6	4.8	2.3	4.1
	Walk	3.4	8.0	1.8	6.0	1.6	2.9		3.9	1.3	4.6
		3.8	7.4	1.8	5.4	1.6	4.0	2.6	4.4	1.8	4.4
	ST mean		5.6		3.6		2.8		3.5		3.1

Horse 24	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.5	8.3	5.4	7.9	4.4	8.2	2.9	6.3	1.2	5.9
	Walk	4.6	7.3	3.3	6.0	2.0	5.1	1.7	4.8	2.6	4.7
		5.1	7.8	4.4	7.0	3.2	6.7	2.3	5.6	1.9	5.3
	ST mean		6.4		5.7		4.9		3.9		3.6

Horse 25	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.3	9.8	6.3	9.4	6.9	9.7	5.3	7.8	3.6	7.8
	Walk	4.7	7.6	5.9	8.3	5.2	7.7	6.0	7.4	4.2	7.4
		6.0	8.7	6.1	8.9	6.1	8.7	5.7	7.6	3.9	7.6
	ST mean		7.4		7.5		7.4		6.6		5.8

Horse 26	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.0	8.1	5.7	9.1	2.9	6.9	1.6	6.6	2.6	6.7
	Walk	5.3	8.4	5.3	8.3	2.6	7.7	2.7	5.6	1.3	6.2
		4.7	8.3	5.5	8.7	2.8	7.3	2.2	6.1	2.0	6.5
	ST mean		6.5		7.1		5.0		4.1		4.2

Horse 27	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.6	9.1	5.5	7.6	2.8	7.0	2.6	6.3	2.4	6.6
	Walk	5.9	7.9	5.6	8.3	6.0	8.7	2.0	8.2	1.4	6.3
		6.3	8.5	5.6	8.0	4.4	7.9	2.3	7.3	1.9	6.5
	ST mean		7.4		6.8		6.1		4.8		4.2

Horse 28	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.5	9.2	7.4	9.2	2.6	7.9	5.5	8.8	3.0	6.2
	Walk	6.3	8.4	4.7	9.0	2.8	7.5	1.2	5.5	2.0	6.9
		6.9	8.8	6.1	9.1	2.7	7.7	3.4	7.2	2.5	6.6
	ST mean		7.9		7.6		5.2		5.3		4.5

Horse 29	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.4	9.3	7.1	9.6	6.3	8.7	4.4	8.6	5.1	8.6
	Walk	6.4	9.5	6.9	9.4	5.7	8.9	5.0	8.5	4.7	7.4
		6.9	9.4	7.0	9.5	6.0	8.8	4.7	8.6	4.9	8.0
	ST mean		8.2		8.3		7.4		6.6		6.5

Ulnaris lateralis

Horse 6	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.5	8.0	4.3	8.1	1.2	7.4	4.0	8.2	0.4	8.2
	Walk	6.8	9.3	6.0	8.1	5.2	8.0	2.3	7.8	3.2	7.6
		6.2	8.7	5.2	8.1	3.2	7.7	3.2	8.0	1.8	7.9
	ST mean		7.4		6.6		5.5		5.6		4.9

Horse 7	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.5	7.8	3.9	8.2	3.5	8.2	2.8	7.5	2.1	6.1
	Walk	5.7	6.4	5.2	5.9	4.4	4.7	3.5	4.8	2.7	4.9
		5.1	7.1	4.6	7.1	4.0	6.5	3.2	6.2	2.4	5.5
	ST mean		6.1		5.8		5.2		4.7		4.0

Horse 8	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	1.3	8.9	2.2	7.9	1.4	7.2	2.4	7.1	1.7	8.8
	Walk	5.5	8.8	6.4	8.1	4.5	8.2	3.4	7.4	3.6	6.8
		3.4	8.9	4.3	8.0	3.0	7.7	2.9	7.3	2.7	7.8
	ST mean		6.1		6.2		5.3		5.1		5.2

Horse 9	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.3	9.0	5.1	8.8	3.5	8.5	5.8	8.7	3.6	7.6
	Walk	5.5	8.7	5.0	8.9	2.8	7.4	0.8	5.4	3.4	7.8
		5.9	8.9	5.1	8.9	3.2	8.0	3.3	7.1	3.5	7.7
	ST mean		7.4		7.0		5.6		5.2		5.6

Horse 10	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.6	7.6	6.7	8.4	4.1	7.3	6.5	9.0	2.3	6.8
	Walk	7.3	9.6	7.0	8.3	6.1	8.4	5.4	7.4	4.2	6.2
		6.0	8.6	6.9	8.4	5.1	7.9	6.0	8.2	3.3	6.5
	ST mean		7.3		7.6		6.5		7.1		4.9

Horse 11	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.2	9.2	6.5	8.7	4.0	7.5	5.4	8.3	3.8	7.7
	Walk	6.7	8.8	7.4	9.4	4.9	8.7	2.4	7.6	4.5	8.1
		7.0	9.0	7.0	9.1	4.5	8.1	3.9	8.0	4.2	7.9
	ST mean		8.0		8.0		6.3		5.9		6.0

Horse 12	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.3	9.5	5.3	9.1	4.1	8.8	3.0	7.0	2.1	7.3
	Walk	5.8	7.7	2.8	8.6	2.7	7.1	4.1	7.4	2.0	5.4
		6.1	8.6	4.1	8.9	3.4	8.0	3.6	7.2	2.1	6.4
	ST mean		7.3		6.5		5.7		5.4		4.2

Horse 13	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.4	9.6	7.1	10.0	7.5	9.0	7.4	8.6	4.8	9.0
	Walk	6.4	8.2	7.2	9.2	4.4	7.4	4.5	6.4	4.6	5.7
		6.4	8.9	7.2	9.6	6.0	8.2	6.0	7.5	4.7	7.4
	ST mean		7.7		8.4		7.1		6.7		6.0

Horse 14	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up			6.5	9.0	7.7	9.0	6.2	9.2		
	Walk	7.3	9.8	6.1	9.7	4.7	9.2	3.7	8.1		
		7.3	9.8	6.3	9.4	6.2	9.1	5.0	8.7		
	ST mean		8.6		7.8		7.7		6.8		

Horse 15	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.1	7.3	5.2	9.2	4.1	8.8	6.5	8.9	1.6	7.8
	Walk	4.7	9.7	6.1	9.3	5.5	9.2	4.0	8.1	5.6	7.8
		4.9	8.5	5.7	9.3	4.8	9.0	5.3	8.5	3.6	7.8
	ST mean		6.7		7.5		6.9		6.9		5.7

Horse 16	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.1	9.1	5.9	9.1	5.3	8.0	4.9	7.1	7.2	9.5
	Walk	6.8	8.9	5.2	8.4	4.1	4.5	3.1	6.5	2.4	4.6
		6.5	9.0	5.6	8.8	4.7	6.3	4.0	6.8	4.8	7.1
	ST mean		7.7		7.2		5.5		5.4		5.9

Horse 17	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up			4.5	7.8	4.7	6.8	4.0	7.1		
	Walk			7.1	9.1	2.5	5.5	4.0	8.5		
				5.8	8.5	3.6	6.2	4.0	7.8		
	ST mean				7.1		4.9		5.9		

Horse 18	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.1	8.4	5.4	7.4	5.3	8.8	3.9	7.2	6.3	9.4
	Walk	6.2	9.5	5.5	8.9	5.4	8.6	4.6	7.9	4.2	7.5
		6.2	9.0	5.5	8.2	5.4	8.7	4.3	7.6	5.3	8.5
	ST mean		7.6		6.8		7.0		5.9		6.9

Horse 19	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.8	8.4	5.1	8.4	4.1	7.9	3.8	7.7	3.3	6.8
	Walk	5.6	9.1	5.5	8.9	6.6	9.4	4.1	8.9	2.5	8.3
		5.7	8.8	5.3	8.7	5.4	8.7	4.0	8.3	2.9	7.6
	ST mean		7.2		7.0		7.0		6.1		5.2

Horse 20	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	6.5	9.0	7.6	9.8	6.8	9.1	4.5	7.5	4.6	8.5
	Walk	4.2	9.0	2.5	8.7	3.3	7.3	3.1	8.5	2.4	7.9
		5.4	9.0	5.1	9.3	5.1	8.2	3.8	8.0	3.5	8.2
	ST mean		7.2		7.2		6.6		5.9		5.9

Horse 21	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	2.6	7.1	2.0	6.4	3.7	7.1	2.3	4.2	2.4	4.3
	Walk	5.4	8.1	5.1	7.9	2.2	3.5	1.2	4.5	2.4	4.1
		4.0	7.6	3.6	7.2	3.0	5.3	1.8	4.4	2.4	4.2
	ST mean		5.8		5.4		4.1		3.1		3.3

Horse 22	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.6	7.9	6.1	9.5	3.7	8.1	1.1	7.0	1.6	6.3
	Walk	5.7	9.4	3.0	7.8	3.8	8.4	2.3	6.9	1.9	5.6
		5.2	8.7	4.6	8.7	3.8	8.3	1.7	7.0	1.8	6.0
	ST mean		6.9		6.6		6.0		4.3		3.9

Horse 23	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	2.9	6.4	3.0	6.2	2.2	6.9	3.7	6.7	1.8	2.6
	Walk	5.6	8.3	3.9	8.7	2.4	7.1	1.8	3.6	1.6	2.5
		4.3	7.4	3.5	7.5	2.3	7.0	2.8	5.2	1.7	2.6
	ST mean		5.8		5.5		4.7		4.0		2.1

Horse 24	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.8	9.0	5.5	8.1	4.5	9.1	2.9	6.7	1.7	5.9
	Walk	5.6	8.5	4.5	6.2	4.5	6.4	2.4	5.0	1.8	3.9
		5.7	8.8	5.0	7.2	4.5	7.8	2.7	5.9	1.8	4.9
	ST mean		7.2		6.1		6.1		4.3		3.3

Horse 25	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.5	8.4	5.6	8.4	6.7	9.4	5.9	7.1	3.4	7.4
	Walk	4.9	7.9	5.4	8.0	5.1	7.5	4.4	5.4	4.1	6.4
		6.2	8.2	5.5	8.2	5.9	8.5	5.2	6.3	3.8	6.9
	ST mean		7.2		6.9		7.2		5.7		5.3

Horse 26	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	4.8	9.0	5.8	8.1	2.5	6.3	2.6	6.8	1.1	5.3
	Walk	4.1	5.6	2.9	3.6	2.0	3.6	1.9	4.9	1.6	5.5
		4.5	7.3	4.4	5.9	2.3	5.0	2.3	5.9	1.4	5.4
	ST mean		5.9		5.1		3.6		4.1		3.4

Horse 27	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.0	8.8	6.9	9.4	6.0	8.7	5.1	8.4	1.4	7.4
	Walk	5.8	9.4	6.0	9.3	5.3	8.0	2.5	7.4	2.9	3.9
		6.4	9.1	6.5	9.4	5.7	8.4	3.8	7.9	2.2	5.7
	ST mean		7.8		7.9		7.0		5.9		3.9

Horse 28	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	7.6	9.5	7.3	9.4	4.6	8.8	6.5	8.7	5.4	8.7
	Walk	5.2	9.1	5.1	8.9	5.3	8.3	3.3	7.3	4.8	5.7
		6.4	9.3	6.2	9.2	5.0	8.6	4.9	8.0	5.1	7.2
	ST mean		7.9		7.7		6.8		6.5		6.2

Horse 29	dB	18		21		24		27		32	
		S	T	S	T	S	T	S	T	S	T
	Back up	5.0	8.9	7.2	10.0	4.3	7.9	5.5	8.2	5.4	8.8
	Walk	7.1	9.5	6.3	9.3	4.3	9.2	4.8	7.8	3.3	8.1
		6.1	9.2	6.8	9.7	4.3	8.6	5.2	8.0	4.4	8.5
	ST mean		7.6		8.2		6.4		6.6		6.4