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Surface condition and its impact on a horse's jump

Bachelor Thesis

University of Veterinary Medicine Vienna

Submitted by

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Index of Abbreviations

AS	Approach stride
DS	Departure stride
EMG	Electromyography
FEI	Fédération Equestre Internationale
g	unit for acceleration based on standard acceleration due to gravity, $9.81 m/s^2$
LF	Leading forelimb
N	Newton
OBST	Orono Biomechanical Surface Tester
SD	Standard deviation
TF	Trailing forelimb
VGT	Vienna Grip Tester
VST	Vienna Surface Tester

1. Introduction

1.1. General Introduction

The equine sport, particularly competition sport, did continuously change throughout the past decades to become one of today's most expensive in the sport sector. As the demands on sport horses increase with competition level as well as equipment and environmental standards, examination of surface conditions is getting greater significance. Especially competition riders, professional as well as amateur, demand higher performances from their horses, jumping higher, wider and better competing at highest levels. Therefor surface conditions experience special attraction in comparison with each other, trying to provide the best possible environmental circumstances. Statements which horses did jump much better/less good on special surfaces due to exempli gratia (e. g.) good/bad maintenance, usage frequency, structure, building and construction or watering are commonly made within competitive conditions.

Hobbs et al., (2014) named performance and soundness as key factors for horse training, affected by both intrinsic and extrinsic factors, the latter including arena surface attributes. Hernlund et al., (2014) did focus on general surface characterization as well as hoof-surface-interaction, while Peterson et al., (2012) did equally on racing surfaces. Furthermore Hernlund, (2016) investigated hoof-surface interactions in show jumping horses on different sand or sand-additive surfaces using accelerometers.

Since research did not provide any specific and precise outcome regarding comparison of both sand and turf surfaces used in show jumping competitions and their impact on performance yet, this study should provide scientifically based redress.

1.2. Objective/Hypothesis

The following thesis examines and compares two different types of surfaces with regard to usage adequacy for show jumping horses in training and competition with the aid of designing an experimental study.

Objective of this study is to show differences between exercising and jumping horses on both sand- and grass-based arena surfaces.

- This study should provide statistically different outcome in testing sand and turf surfaces due to stiffness and grip.

  Hypothesis 1: The grip is higher on grass than on sand surface.

  Hypothesis 2: Stiffness is higher on grass than on sand surface, therefor displacement is higher on sand than on grass.

- This work shows the influence of different surfaces to the musculoskeletal system of the horse. Different surfaces show verifiable impact on the horse's jump.

  Hypothesis 3: The leading forelimb shows higher acceleration values at landing than the trailing forelimb.

  Hypothesis 4: Landing shows higher acceleration values than take off in both leading and trailing forelimb.

  Hypothesis 5: Approach and departure strides show no differences regarding acceleration within surfaces.

  Hypothesis 6: Approach strides as well as departure strides show higher acceleration values on turf than on sand surface.

  Hypothesis 7: Leading and trailing forelimb show no differences regarding acceleration within surfaces.

2. Literature review

2.1. Surfaces and Surface Characteristics

As we can notice a growth in Fédération Equestre Internationale (FEI) events all around the world (FEI 2013) over the last 15 years, including also Europe, the focus on equine health and welfare within competition increased relatively. Talking about welfare, both intrinsic and extrinsic factors take center stage influencing soundness as well as performance in horses (Fig. 1).

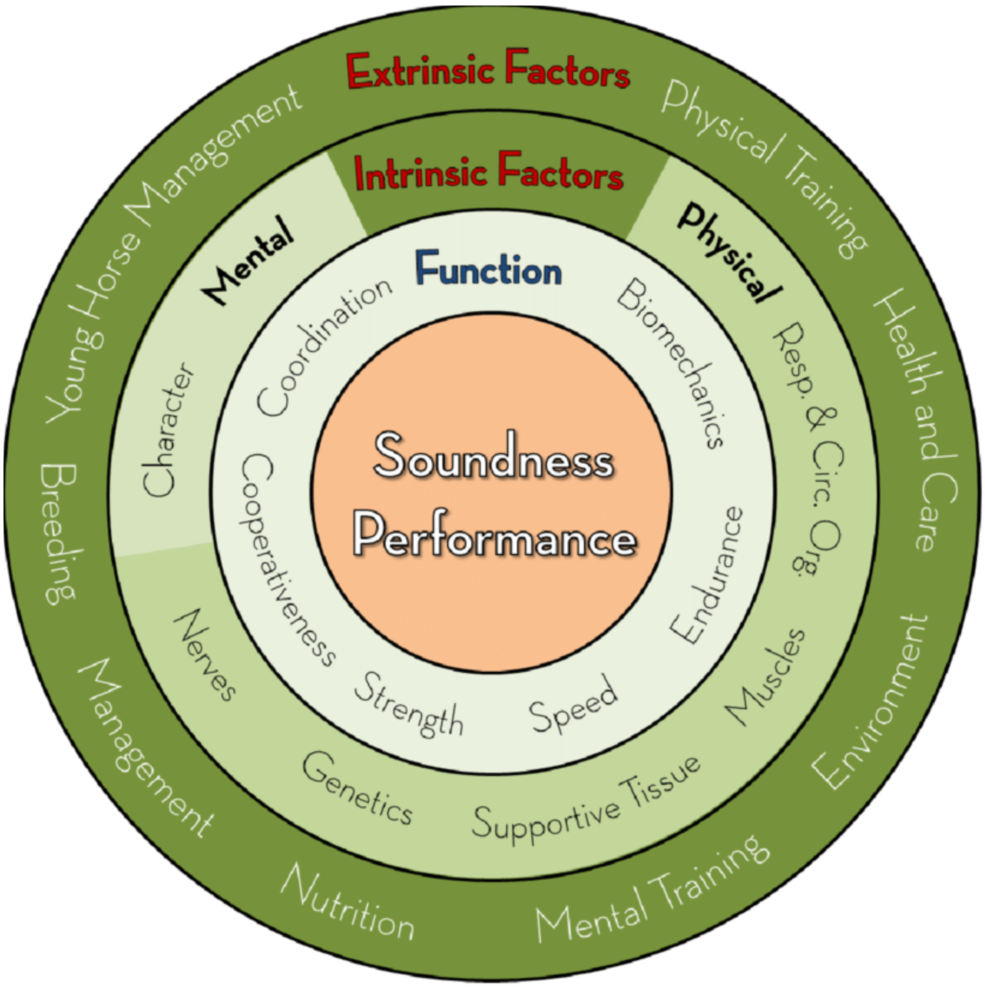

Fig. 1: Key factors influencing soundness and performance (Hobbs et al., 2014)

Referring to extrinsic factors consideration of the environment, in particular surface conditions, it is nowadays documented (Egenvall et al., 2013, Murray et al., 2010a, Murray et al., 2010b) that different surfaces do influence the risk of injuries in training and competing and are associated with appearance of lameness. Especially arena's surface and location variations, as well as usage frequency and maintenance are related to injury likelihood. Furthermore, sand-based surfaces showed the greatest risk for injury, just as a sudden change of surface or its condition increased such risks for horses adapted to a certain surface (Murray et al., 2010a).
During the last decades a development towards increasing usage of artificial surfaces (e.g. sand, sand and additives, woodchips etc.) rather than natural ones. Most common used surfaces in dressage riders referring to the UK are sand and rubber mixtures (Fig. 2), while natural turf surfaces are used much less (Murray et al., 2010b) which may be related to higher difficulty in maintenance and difficulty regarding weather-influenced usage possibilities (Hobbs et al., 2014).

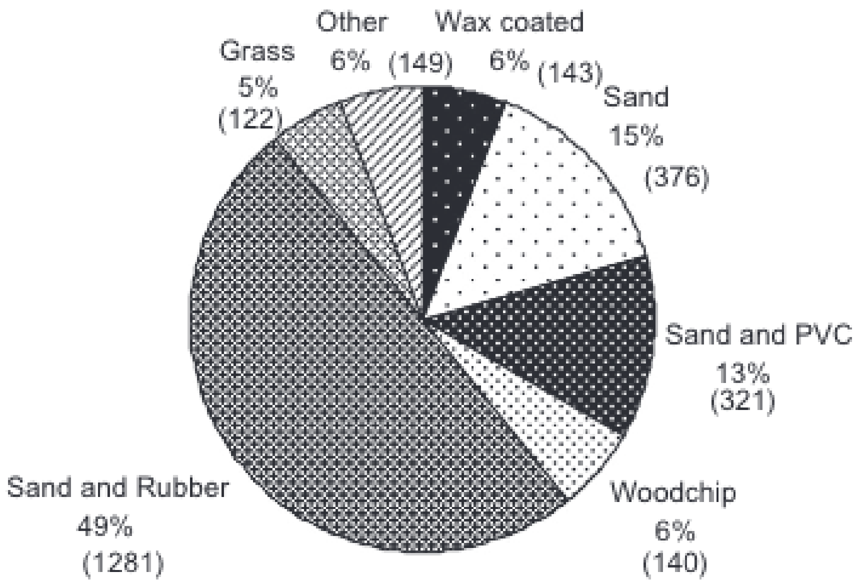

Fig. 2: Pie chart showing the proportion of different categories of arena surface types most commonly reported to be used for training of registered British Dressage horses (Murray et al., 2010b).

Comparing sand and turf surfaces preliminary studies showed significant differences due to deceleration peaks, more accurately occurrence. It is documented by Hernlund et al. (2010), that aforementioned peaks occur later in sand-based surfaces than turf ones, probably caused by a loose top layer allowing the horse's hooves to slide during landing phase. In addition, the horse's ability to adapt to different surfaces (resulting from diversified training) is of great significance.

With regard to Hobbs et al. (2014) Hernlund et al. (2017) measured defined terms describing essential surface properties (e. g. grip) by using the Orono biomechanical surface tester (OBST) to compare different surface and warm-up arenas throughout Europe, including sand and turf surfaces with the outcome of significant differences within functional properties.

Differentiating types of sand-based arenas, wax-coated or sand and rubber surfaces can be associated with lower injury risks than sand only, sand and PVC or grass surfaces, in addition fine sand should be given priority compared to coarse sand, as well as small rubber chunks compared to larger ones (Murray et al., 2010b).

Furthermore Hobbs et al., (2014) defined a variety of functional properties and characteristics to influence surface performance and suitability for the horse sport industry, considering stiffness and grip as well. Whereas stiffness is defined as the ratio of applied force to deflection (Nigg and Yeadon, 1987), meaning surface resistance to deformation under an applied load (Hobbs et al., 2014), grip is known as the affection on a horse's hoof sliding during landing, turning and pushing off (Hobbs et al., 2014). In relation to define surface's qualities, both stiffness and grip need to be included in evaluations. Stiffness in particular is assumed to influence the frequency of injuries in human sports, whereby "hard" surfaces are more likely to cause injury than "soft" surfaces (Hong and Bartlett, 2008). Similar statements regarding horse sports can be found in recent studies (Barrey et al., 1991, Murray et al., 2010b). Hernlund et al., (2014) stated grip as a key factor to be determined by friction and therefor hoof landing, which is why a grip too high stopped the horse's hoof too quickly, whereas less grip resulted in a slippery surface, both increasing injury risk. Hence a right balance of grip is to be desired to ensure suitable riding surfaces.

2.2. Show Jumping

Previous studies already verified different ground reaction forces and joint moments due to different forelimb placement within jumping horses, resulting in high tendon loading during landing, which is larger in trialing compared to leading forelimb (Meershoek et al., 2001). Contemplation of the jumping mechanics (Fig. 3) reveal different ground reaction forces regarding leading and trailing forelimb within all strides from approach to departure (Schamhardt et al., 1993).

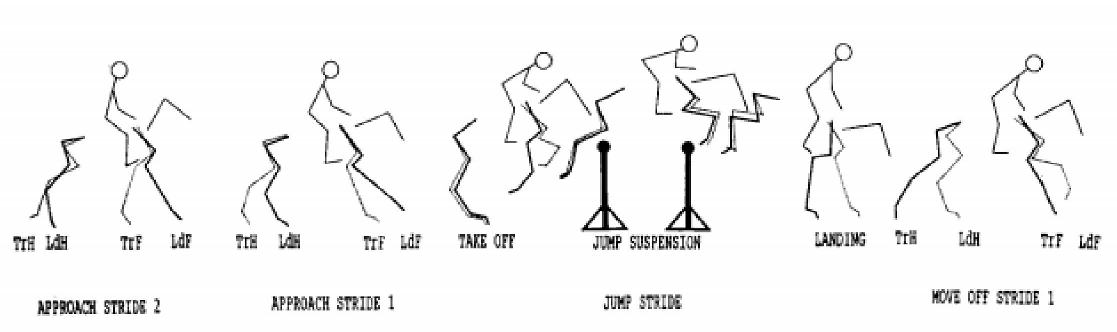

Fig. 3: Terminology for the strides and individual limbs during approach, jump and departure (Clayton, 1989)

A preliminary accelerometric study by Barrey and Galloux (1997) using only one transducer fixed at the horse's thorax over the caudal part of the sternum measuring dorsoventral acceleration (Fig. 4) verified individual jumping techniques, depending on training condition and jumping ability, in turn affecting measured acceleration peaks of the individual limbs during take off and landing, which only validated earlier research results: forelimbs showed greater acceleration peaks than hindlimbs in both take off and landing measurements (Barrey and Galloux, 1997, Schamhardt et al., 1993).

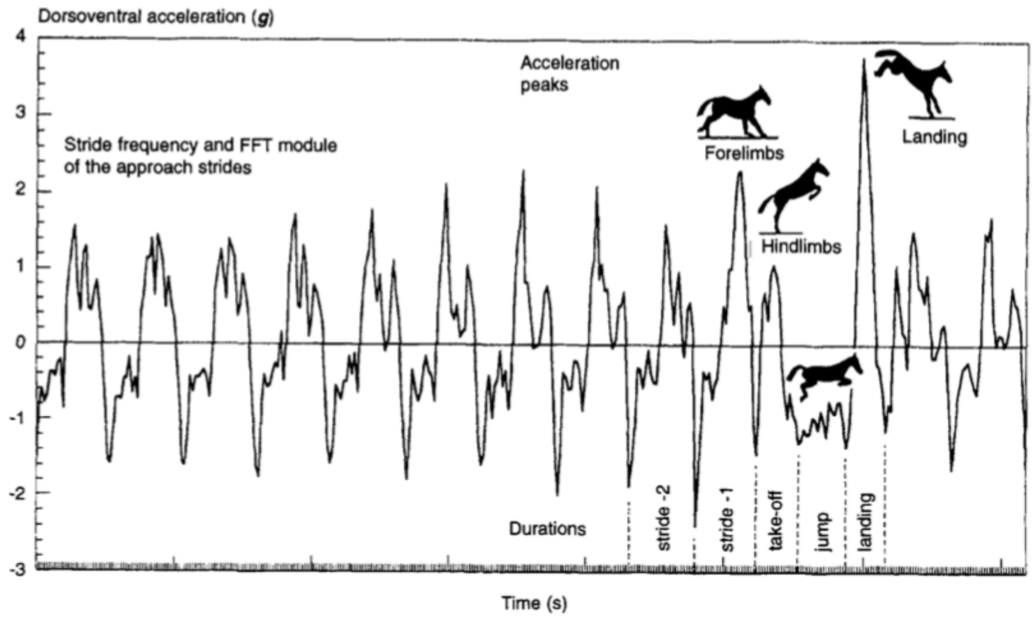

Fig. 4: Example of a dorsoventral acceleration recording of the approach, jump and move off strides (Barrey and Galloux, 1997).

Shock absorption individually regarding forelimbs, the trailing limb withstands highest force during landing due to ground contact with almost vertical orientation, whereas the leading forelimb exerts higher braking forces (Hernlund et al., 2010, Clayton and van Weeren, 2013). Therefore, the trailing forelimb verifiably takes highest loads during landing considering the suspensory apparatus (Schamhardt et al., 1993, Meershoek et al., 2001). Moreover, comparison of different sand-mixture show jumping surfaces showed substantiation of aforesaid results and additionally demonstrated higher horizontal ground interaction at a canter in leading limbs (Hernlund et al., 2013, Hernlund, 2016).
Hernlund (2016) demonstrated different speed and landing trajectory in leading and trailing forelimbs on a sand and turf surface by video analysis, as well as different effects on hoof-surface impact while jumping on surfaces with different compositions and elevated impact hoof-shock, in particular concerning forelimb landing.

By virtue of this knowledge highest demands are placed on surfaces used in exercising and in particular jumping horses, increasing proportionate to obstacle heights.

3. Material and Methods

3.1. Arena Surfaces

Two different outdoor arenas were compared to perform the following studies, both placed in the same private riding facility in Lower Austria, near Vienna. An overview of arenas included in the study is documented in Fig. 5.

Arena I is a sand-based surface, with a top layer of quartz sand and additive mixture over an ebb and flow system, a drainage system applicated in sand substrate over gravel, construction materials manufactured by “Magyer GmbH”. The additives are a mixture of textile fibre and fleece chaffs. The water level in the outdoor arena with a size of 50x75 m is adapted manually via the ebb and flow system due to weather influences to increase or decrease moisture content. The arena is used permanently during outdoor season as well as during winter whenever allowed by weather circumstances. Daily maintenance and ground care are implemented to loosen and compact the surface where needed by using a tractor-mounted grader. Once or twice a year the surface is deep-harrowed, relevelled and topped up with sand and fibre if necessary. Purchase of new fibre materials varies among different suppliers, therefor clear definition of composition proves to be rather difficult.

Arena II is a turf surface with a simple grass cover over basic soil with a size of 55x90 m. This arena is usually not used for riding or jumping horses at the private facility, therefor also no special attention is payed regarding maintenance. Arena II is rather used to build paddocks during outdoor season. Root structure and moisture level depend on weather as well as atmospheric conditions. The grass is mowed by hand or grazing horses and once a year grass seeds are scattered where needed. No specific watering routine is applied as usually practiced in training facilities; the surface is irrigated irregularly by means of rain. Nevertheless, no special preparation was required to use Arena II for performing the study.

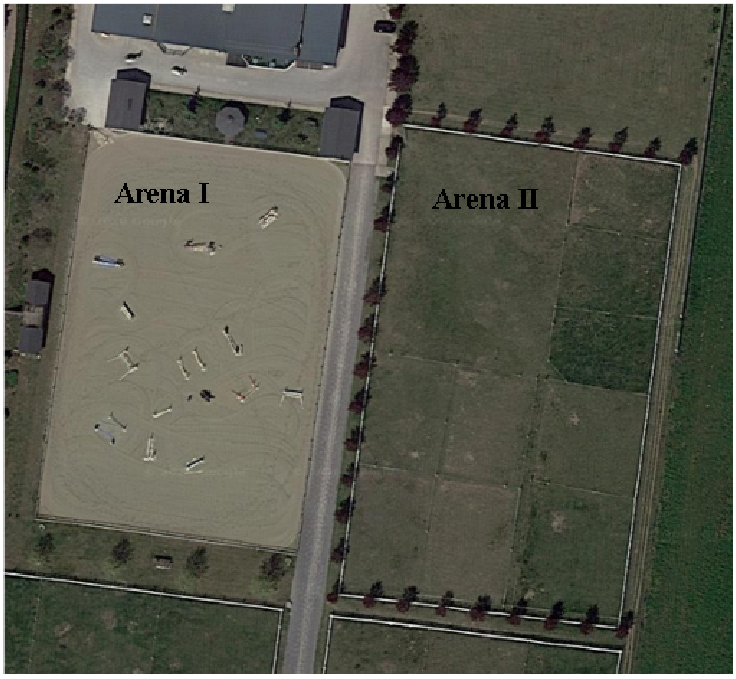

Fig. 5: Arena overview (www.earth.google.com; accessed 6.5.2020)

3.2. Soil Moisture Probe

Moisture measurements of both Arena I and Arena II were done via a measuring device (IMKO–HD2, IMKO, Germany) suitably equipped with a Soil Moisture Probe (TRIME–Pico 64, IMKO, Germany) (Fig. 6, Fig. 7).

Before starting subsequent measurements, humidity data was collected at 5 random positions throughout Arena I and Arena II to find average moisture level. A test run was performed a few weeks before study conduct (14.07.2015), a second run during the study itself (05.10.2015).

Fig. 6: Soil Moisture Probe

Fig. 7: Soil Moisture Probe (www.imko.de; accessed: 6.5.2020)

3.3. Vienna Surface Tester (VST)

The Vienna Surface Tester (Fig. 8) is a prototype of a measuring device invented and built by the Movement Science Group, Department of Companion Animals and Horses, University of Veterinary Science Vienna. A simple bowling ball with a diameter of 20 cm was modified and equipped with two accelerometers to analyse surfaces, the final draft weighing about 6.15 kg. “The Ball” provides an effective means to measure impact speed, impact energy, deceleration, stiffness, displacement, energy restitution, force reduction and resonance frequency. All data recorded by the VST is sent to a memory card for evaluation and further analysis via computer.

Measurements were performed at Arena I as well as Arena II in parallel with Moisture measurement, id est (i.e.) a test run in July 2015 and the second run during study conduct (05.10.2020). Dropping of “The Ball” for about 30–40 times at several randomly selected positions within the arenas from different heights between 5 cm up to 150 cm revealed data concerning aforesaid surface characteristics, sent to the memory card.

Analyzation of VST measurements in conjunction with surface moisture was required, therefor data regarding latter was collected as mentioned above.

Fig. 8: Vienna Surface Tester, “The Ball”

3.4. Vienna Grip Tester (VGT)

The Vienna Grip Tester (Fig. 9) is a measuring prototype invented and built by aforementioned Movement Science Group just as the VST. It is a device to measure grip via a gas pressure spring, electively used with affixing add-ons of either a bare hoof or a horseshoe with studs, pressed to the surface with 700 Newton (N). Using a torque wrench performing a 45 degree turn measures maximum torque proportionate to grip measurement ($n\mu = \frac{Tmax}{FnxRxL} L = 0.3$).

The procedure as explained above was performed ten times in randomly selected positions with both bare foot and horseshoe add-on within Arena I as well as Arena II, taking surface moisture in account for data analysis just as regarding VST-data. Implementation of measurements was performed in duplicate designs corresponding to VST and moisture measuring.

Fig. 9: Vienna Grip Tester – utilization

Fig. 10: Grip Measurements in Arena I and Arena II

3.5. Horses and Riders

For the accelerometer study four different riders rode nine middle aged (9.45 years +/- 2.6) warm blood show jumpers (n=9), participation of the tenth planned horse was not possible due to unexpected health issues. Of the four riders two were professionals (Rider A, Rider

B), the other two amateur riders (Rider C, Rider D), all of them attending show jumping competitions on a regular basis with the horses ridden during the study.
All horses were based at the riding facility, therefor horse's adaption to arena I due to daily training and arena II due to paddock-usage can be expected.
A Summary of detail information regarding horses and horse-rider-combinations included in the study from 2015 is presented in Table 1.

All horses were in regular training, daily workout routine and healthy. The following accelerometer study was approved by the Animal Welfare Committee of the University of Veterinary Science.

Horse	Sex	Year of birth	Age in 2015	Rider
Horse 1	Gelding	2009	6	Rider A
Horse 2	Gelding	2005	10	Rider A
Horse 3	Mare	2009	6	Rider A
Horse 4	Mare	2004	11	Rider A
Horse 5	Mare	2006	9	Rider A
Horse 6	Gelding	2006	9	Rider B
Horse 7	Gelding	2007	8	Rider C
Horse 8	Gelding	2002	13	Rider B
Horse 9	Mare	2002	13	Rider D

Tab. 1: Summarized Horse-Data

3.6. Accelerometer Study

For the actual main study nine abovesaid horses were used in order to directly compare surface influence to their jump. The study was performed over two consecutive days: five horses were ridden by Rider A on the first day (05.10.2015; 09:00–13:00), the remaining four horses by Rider B, Rider C and Rider D on the second day (06.10.2015; 14:00–17:30). The night before starting the study it was lightly raining, therefor surface moisture increased minimally. During the first day the study was performed under an overcast sky with moderate ray of sunshine. The night before second performance day was foggy, throughout the second day it was clouded more heavily than the previous day.

Each horse-rider-pair was equipped with four wireless Electromyography (EMG) accelerometers (Trigno Wireless System and Trigno Avanti Sensors, DELSYS) overall (Fig. 11), usually used to record muscle activity complementing movement studies. In the following study the sensor's non-invasive capacity to record acceleration was used for surface evaluation, analyzation and comparison.

Fig. 11: DELSYS Equipment (www.delsys.com; accessed: 6.5.2020)

Two accelerometers were attached on both distal limbs of all nine horses, more precisely on the lateral cannon bone of both left (Sensor 1) and right forelimb (Sensor 2). The sensors were fixed via tape and bandages to ensure highest possible mobility limitation, no direct skin contact was required for needed statistical records.

The two residual sensors were affixed on both the region of the horse's sternum (on the saddle girth; Sensor 3) and the rider's lumbar spine (on the belt; Sensor 4) by taping.

Exact accelerometer placement is illustrated below (Fig. 12).

Fig. 12: Accelerometer overview (Horse 3, Rider A)

Both arenas were prepared for the series of tests, Arena I was graded shortly before starting the study. A vertical jump was built in both Arena I and Arena II placed with a ground bar in front. All horses were flat worked as usually before jumping training, for warming up they had to overcome the obstacle a few times with only one fence bar placed at a height of about 0.8 m and a ground bar in front with a distance of about 2.5 m to ensure comparable approach of all horses. Subsequently the vertical jump was increased to actual study-height with two bars placed on the obstacle at a height of 0.8 m and 1.10 m and a ground bar in front with a distance of 3.2 m. Before starting measurements each horse-rider-constellation did overcome the jump sequence at aforementioned height one or two times before starting data recording.

For final data evaluation and recording each horse-rider-pair had to overcome the jump sequence (Fig. 13) five times in a row uninterruptedly first in Arena I followed by Arena II, whereof sequential analysis of respectively three approach strides, take off, landing and three move off/departure strides was conducted for the purpose of comparing surface influence on the horse's jump.

Fig. 13: Visualization of a jump sequence in Arena I and Arena II (Horse 5, Rider A)

3.7. Data processing

Data evaluation was carried out in Microsoft Excel or in SPSS.

3.7.1. Moisture Measurement, VST and VGT

Collected moisture data form Arena I and Arena II was compared by building mean value and standard deviation (SD).

To evaluate and analyze grip data, mean value and standard deviation were calculated and normal distribution was verified with the help of the Kolmogorov-Smirnov-Test. As apart from one data series, all showed normal distribution, VGT-data was further analyzed via TTest for paired samples, comparing sand and turf surface as well as differences concerning bare foot and horseshoe add-ons. Regarding one not normally distributed series of data the Wilcoxon Rank Test was used. The results from Arena I and Arena II were depicted as a boxplot.

Regarding VST-data, results were visualized in diagrams, covering deceleration peak, stiffness, displacement, energy restitution, force reduction and resonance frequency. Stiffness was further tested due to normal distribution and analyzed and compared via TTest for paired samples.

3.7.2. Accelerometers

Concerning accelerometer data, results were further processed in Excel. As all four accelerometers revealed acceleration values for x-, y- and z-plane, total acceleration was calculated. Furthermore, data was divided into the five separate jumping sequences and acceleration peaks were determined. Mean values were built to make data directly comparable.

3.7.2.1. Statistics

The Kolmogorov-Smirnov-Test was used, revealing normal distribution throughout almost all measurements. In addition, the TTest for paired samples was used to compare relevant values ascertained (Wilcoxon).

4. Results

4.1. Moisture

Moisture measurements were performed as mentioned in chapter 3.7.1.

Results showed significantly higher moisture level on sand (28 %) compared to turf surface (13 %, p=0.000) (Tab. 2).

Moisture (%)						**Mean**	**SD**
Measurement	1	2	3	4	5		
Turf	12.84	11.64	13.87	13.65	14.46	13.3	1.1
Sand	28.75	29.92	27.54	28.2	28.75	28.6	0.9

Tab. 2: Moisture measurement

4.2. VGT

VGT-measurement was collected as followed revealing higher grip on turf compared to sand surface regarding horseshoe as well as bare hoof ad-on (Fig.14). Boxplot below show similar form regarding bare hoof values with rather symmetrical quartiles and withers on turf as well as sand surface. Horseshoe measurements appear more variable, but differ not very pronounced.

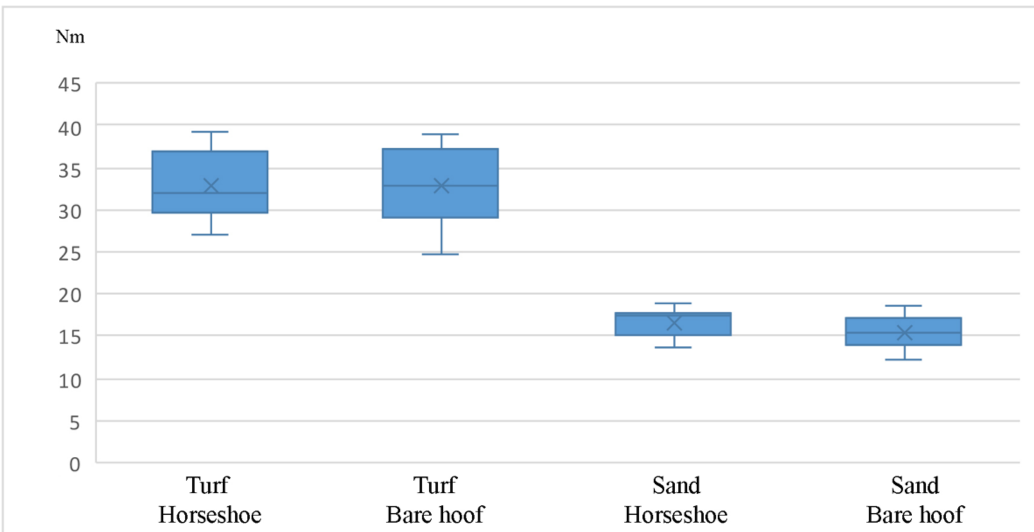

Fig. 14: Boxplot grip

The Kolmogorov-Smirnov-Test revealed normal distribution throughout almost all measurements, except horseshoe on sand.

Comparison of arenas among each other showed differences between sand and turf surface, regarding horseshoe (p=0.005) and bare hoof (p=0.000) ad-on, whereas comparison within surfaces didn't show differences between horseshoe and bare hoof on turf (p=0.910) and sand (p=0.126).

Furthermore, the landing point in both arenas was documented via photography (Fig. 15, Fig. 16).

Fig. 15: landing point Arena I

Fig. 16: Landing point Arena II

4.3. VST

The VST collected data as followed (Fig. 17 – Fig. 28).

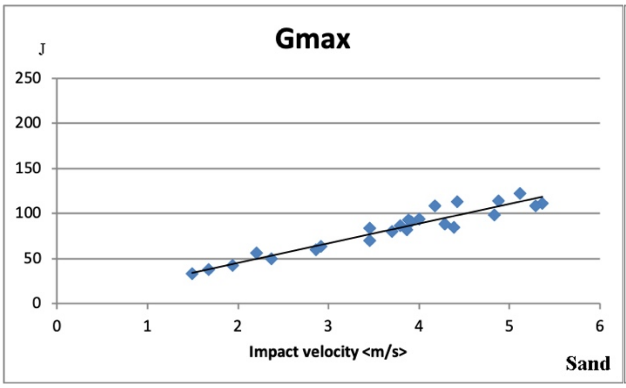

Fig. 17: Deceleration peak Arena I

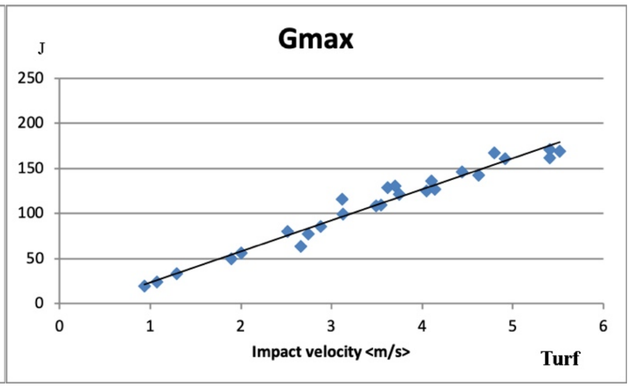

Fig. 18: Deceleration peak Arena II

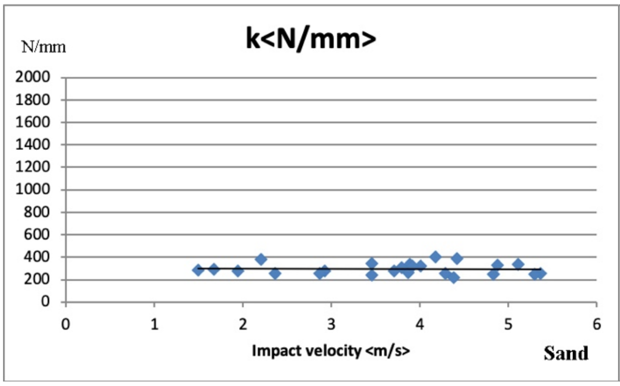

Fig. 19: Stiffness Arena I

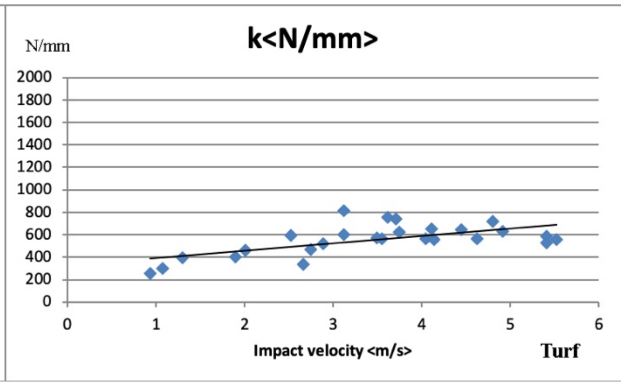

Fig. 20: Stiffness Arena II

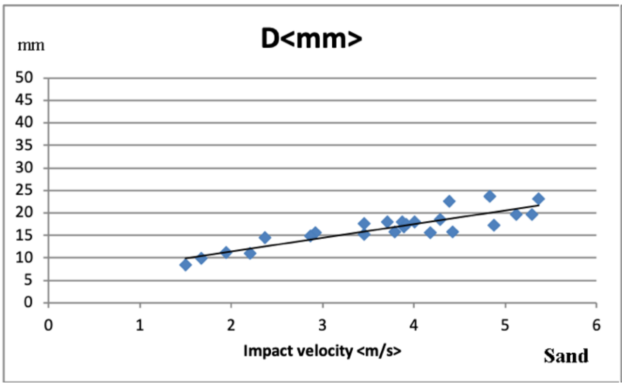

Fig. 21: Displacement Arena I

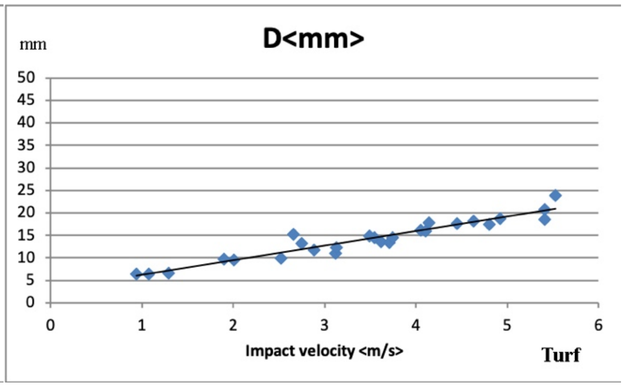

Fig. 22: Displacement Arena II

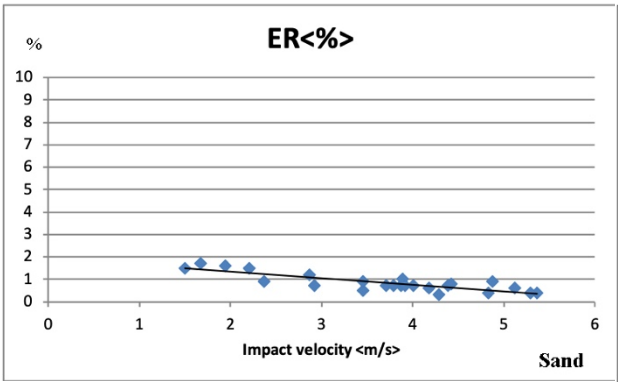

Fig. 23: Energy restitution Arena I

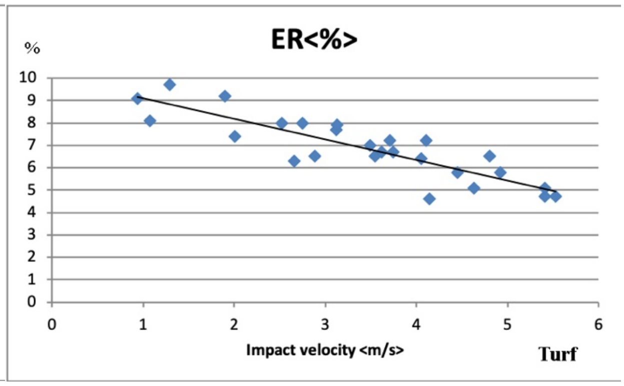

Fig. 24: Energy restitution Arena II

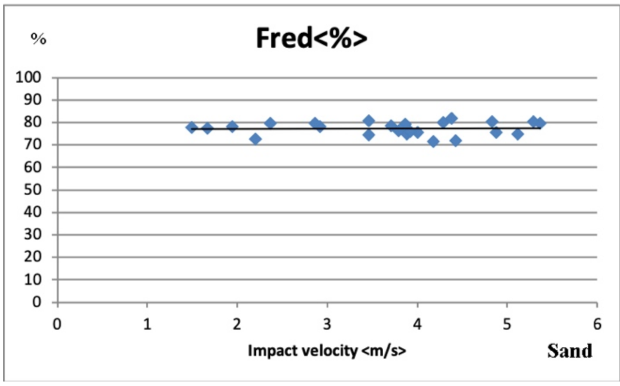

Fig. 25: Force reduction Arena I

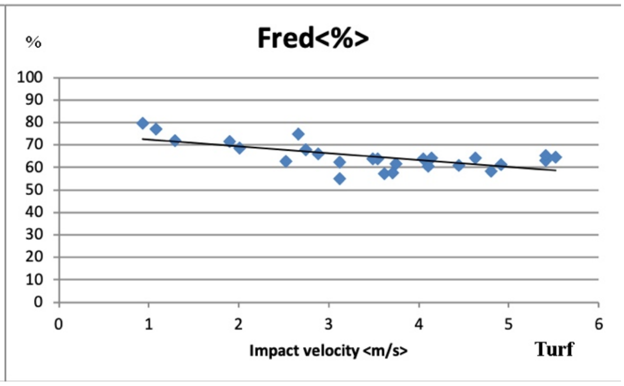

Fig. 26: Force reduction Arena II

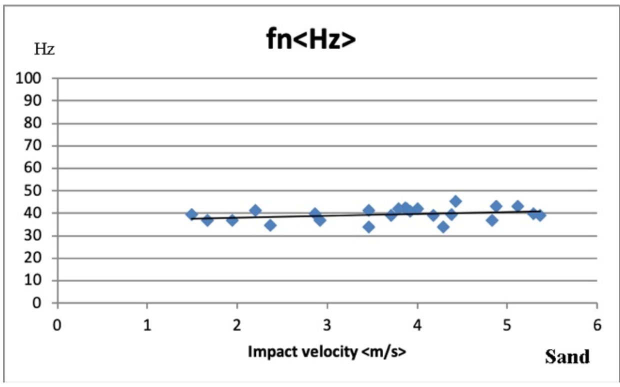

Fig. 27: Resonance frequency Arena I

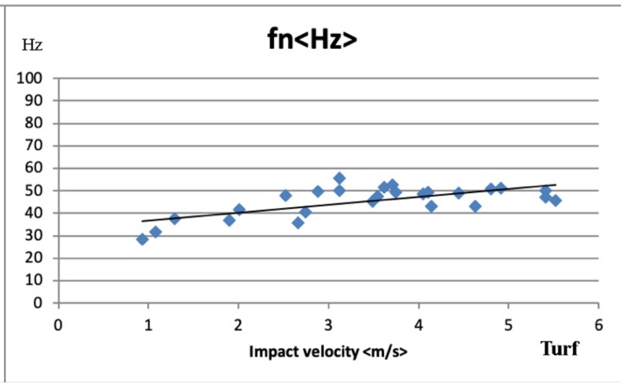

Fig. 28: Resonance frequency Arena II

Regarding stiffness the TTest for paired samples revealed statistically significant differences between sand and turf surface (p=0.000) which is also visualized in the boxplot below (Fig.29). Turf surface showed a consistently symmetrical range regarding median and quartiles, whereas sand surface showed only approximately similar symmetricity.

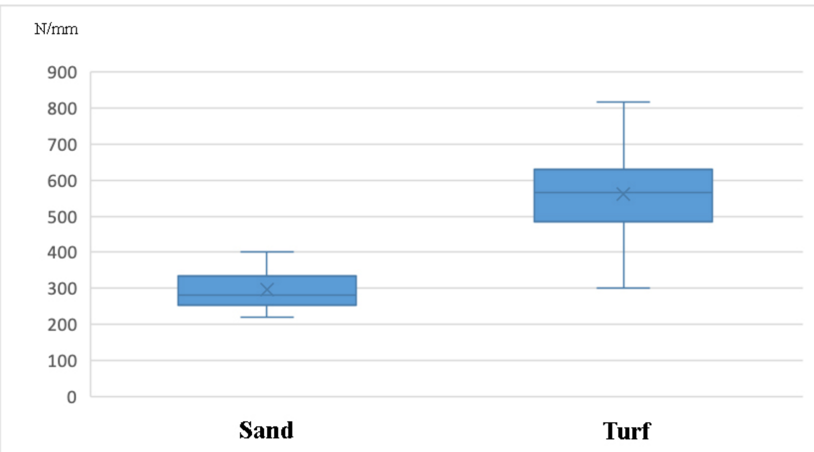

Fig. 29: Boxplot stiffness

4.4. Accelerometer

Analyzation of each horse showed individual movement patterns and characteristics regarding gallop strides. Throughout the study the horses didn't change those individual movement characteristics throughout different arenas, but well changed acceleration peaks. By way of illustration, acceleration diagrams of a jumping sequence of the leading limb of the same horse on sand and turf is contrasted below (Fig. 30, Fig. 31).

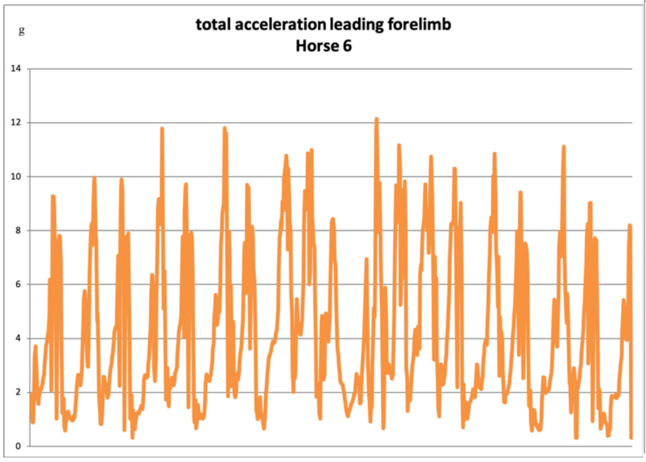

Fig. 30: Leading forelimb on sand

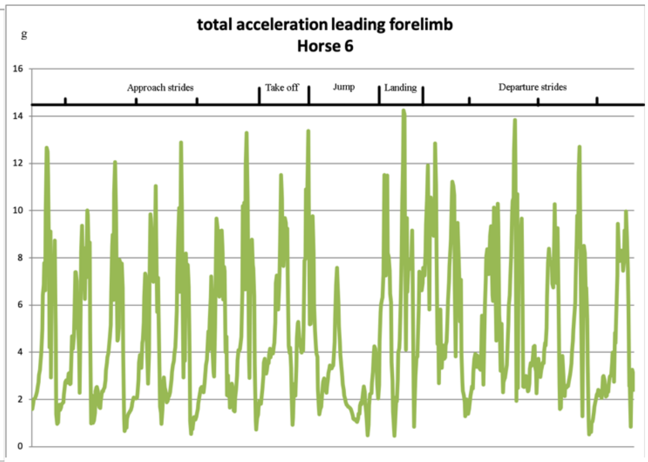

Fig. 31: Leading forelimb on turf

Terminology defining abovementioned diagrams is used as mentioned in chapter 2.2 (Fig. 3, Fig. 4).

As raw data only concerned either left or right forelimb, overlay of both jump sequences determined leading and trailing limb (Fig. 32). As the leading limb is defined as the first limb to be moved forward but the second to land, the trailing forelimb is defined as the first limb to land. Regarding subsequent diagram left forelimb turns out to be trailing, right forelimb leading.

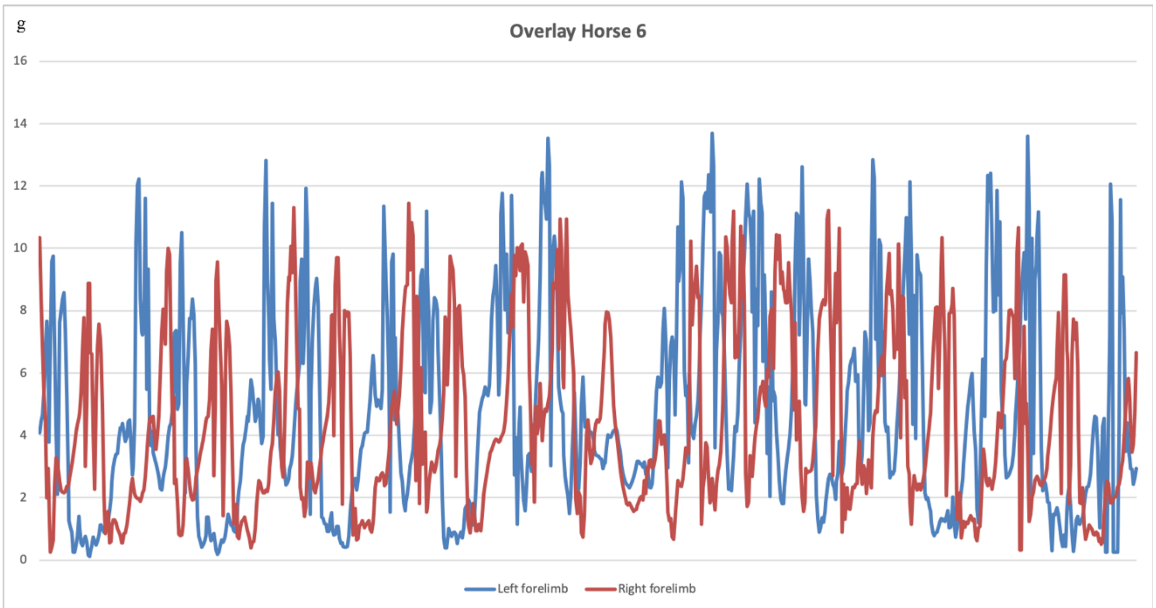

Fig. 32: Overlay jump sequence

Further consideration showed distribution of values determined, on the one hand comparing leading (LF) and trailing (TF) forelimb during approach strides (AS) on sand as well as grass (Fig. 33) and on the other hand take off and landing on both surfaces (Fig. 34).

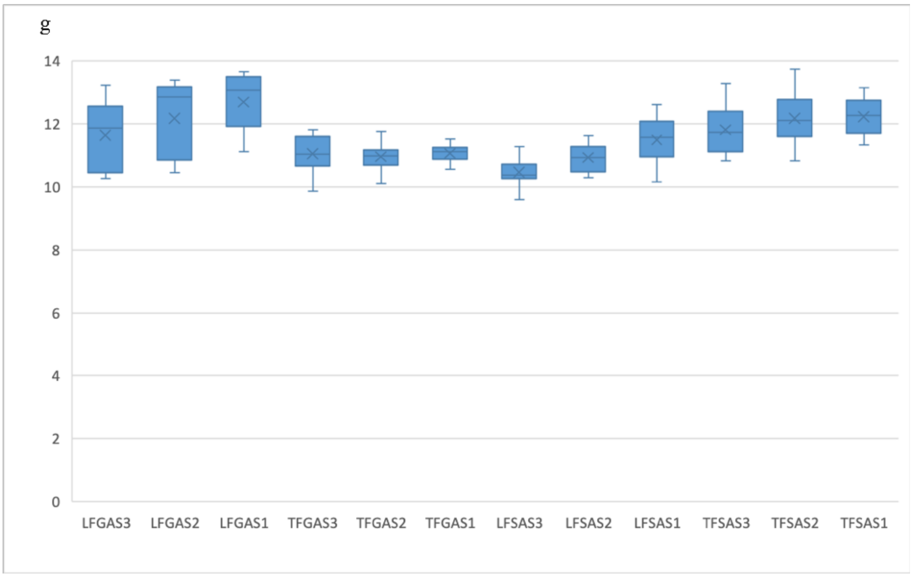

Fig. 33: Boxplot approach strides on sand and grass

The range of determined values did vary the most within approach strides regarding LF on grass, as well as TF on sand. The range of TF on grass as well as LF on sand did show less variations of acceleration. The interquartile range of LF on grass shows highest asymmetry concerning skewness as well as most of interquartile range of TF on grass. On the contrary LF and TF on sand show symmetrical interquartile range throughout almost all values but all the more, longer whiskers can be found proportionately within boxplot range. TF on grass as well as LF on sand respectively show less variability and higher symmetricity concerning quartile and interquartile range.

Contemplating take off and landing the range varies the most within landing data, in LF as well as TF. Whereas the interquartile range is almost symmetrical throughout evaluation regarding take off, in contrast landing shows the only outliner within TF on grass.
Further comparison of take off and landing via Kolmogorov-Smirnov-Test reveals normal distribution and two-sample TTest shows significant differences regarding LF on turf ($p=0.006$) and sand ($p=0.05$), but not for TF on turf ($p=0.62$) as well as sand ($p=0.73$).

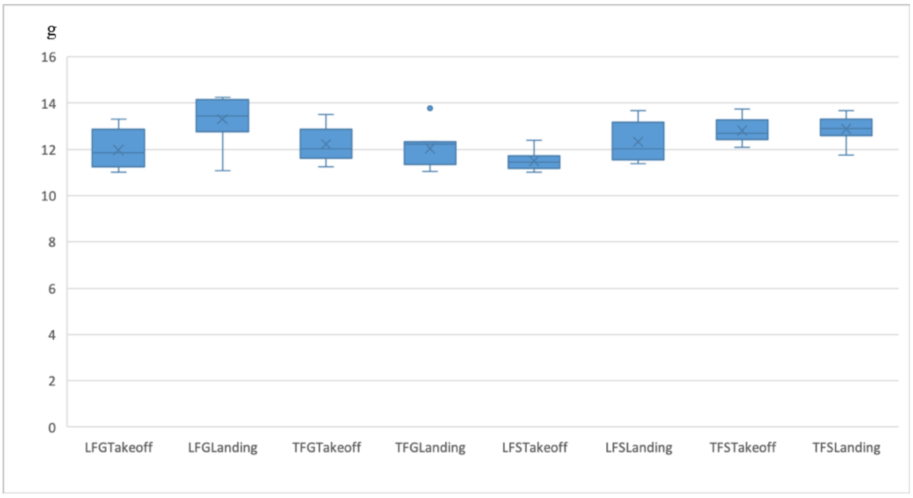

Fig. 34: Boxplot take off and landing on sand and grass

Pairs		Mean of paired differences	SD of paired differences	p-value
LF grass AS3	LF sand AS3	1.17700	1.39692	0.035
LF grass AS2	LF sand AS2	1.23494	1.22142	0.016
LF grass AS1	LF sand AS1	1.19825	0.95712	0.006
LF grass take off	LF sand take off	0.47522	0.82599	0.123
LF grass landing	LF sand landing	0.97610	1.15786	0.035
LF grass DS1	LF sand DS1	0.77515	0.96684	0.043
LF grass DS2	LF sand DS2	1.01279	0.87351	0.008
LF grass DS3	LF sand DS3	1.12694	0.92032	0.006
TF grass AS3	TF sand AS3	-0.76038	0.96948	0.046
TF grass AS2	TF sand AS2	-1.21162	0.98665	0.006
TF grass AS1	TF sand AS1	-1.16951	0.65138	0.001
TF grass take off	TF sand take off	-0.59945	1.01003	0.113
TF grass landing	TF sand landing	-0.84356	1.01512	0.037
TF grass DS1	TF sand DS1	-0.06608	0.38373	0.619
TF grass DS2	TF sand DS2	-0.72902	0.48738	0.002
TF grass DS3	TF sand DS3	-0.72007	0.86710	0.037

Tab. 3: Comparison between surfaces

Table 3 provides information about the single subdivided parts of a jump sequence directly compared between surfaces. Detailed comparison of first LF on grass to sand show significant differences concerning all three approach strides (p=0.035; p=0.016; p=0.006) as well as all three departure strides (p=0.043; p=0.008; p=0.006). Furthermore, consideration of TF on sand delivers similar results, significant differences can be found regarding all three approach strides (p=0.046; p=0.006; p=0.001), whereas analyzation of departure strides highlights one insignificant result concerning DS1 (p=0.619) as a unique exception within simple strides. DS2 and DS3 again show significant differences comparing sand to turf (p=0.002; p=0.037). Taking a closer look on take off reassembles above mentioned results from DS1 by showing insignificant differences as well, not only on sand but also on turf. Expectedly, landing constitutes steady outcome as both LF (p=0.035) and TF (p=0.037) on sand and turf surface differ significantly.

Pairs		Mean of paired differences	SD of paired differences	p-value
LF grass AS3	TF grass AS3	0.58064	1.17495	0.176
LF grass AS2	TF grass AS2	1.21214	1.35473	0.028
LF grass AS1	TF grass AS1	1.63629	0.79050	0.000
LF grass take off	TF grass take off	-0.24378	1.22324	0.566
LF grass landing	TF grass landing	1.26494	1.74452	0.061
LF grass DS1	TF grass DS1	0.24808	0.81032	0.385
LF grass DS2	TF grass DS2	0.77954	1.11645	0.070
LF grass DS3	TF grass DS3	0.30755	1.13694	0.441
LF sand AS3	TF sand AS3	-1.35674	1.04689	0.005
LF sand AS2	TF sand AS2	-1.23441	1.21283	0.016
LF sand AS1	TF sand AS1	-0.73148	1.08536	0.078
LF sand take off	TF sand take off	-1.31845	0.74828	0.001
LF sand landing	TF sand landing	-0.55472	1.16608	0.191
LF sand DS1	TF sand DS1	-0.59314	1.02724	0.121
LF sand DS2	TF sand DS2	-0.96226	1.60737	0.110
LF sand DS3	TF sand DS3	-1.84701	0.60574	0.000

Tab. 4: Comparison within surfaces

Table 4 comprises information about respectively comparing LF to TF within the same arena. The results vary throughout the jumping sequence on grass as well as sand surface. Regarding landing no differences can be found between LF and TF in Arena I (p=0.191) as well as Arena II (p=0.061). Analyzation of take off shows significant differences between LF and TF on sand (p=0.001), then again insignificance on turf (p=0.566). Approach as well as departure motion sequences consequentially yield a wide variation range of results. 41.7% of the simple strides show differences (grass AS2, grass AS1, sand AS3, sand AS2, sand DS3), whereas 58.3% differ insignificantly. Accumulation of significant differences within approach strides rather than departure strides is noted.

5. Discussion

Direct comparison of riding surfaces to decide upon suitability for training as well as jumping horses is commonly practiced nowadays with particular focus on the horse's welfare. As according to Murray et al. (2010b) we can see a trend toward sand-based surfaces the relevant question is whether this trend reversal is seen due to welfare of the horse or easier surface management and human convenience. The VGT-detected substantially higher grip on turf surface compared to sand-based surface may be indicator to horse comfort being paramount. As underpinned by previously mentioned VGT results, Hypothesis 1 is supported by our results. Placing special focus on the landing points in both Arena I (Fig. 15) and Arena II (Fig. 16) and analyzing the hoof prints on both surfaces, slip resistance can be interpreted due to visible sliding marks. As the slipping phase is shorter on turf compared to sand surface, a connection between grip and slip resistance is assumed. Turf surface shows higher grip and therefore less slipping, whereas sand shows less grip and in turn higher slipping, which is why we talk about reciprocally proportional results.

However, this doesn't mean that higher or lower friction is automatically better or worse for the totality of horses. As sand quality, maintenance intervals and moisture level are highly influential factors within sand-based surfaces, those factors influence shear strength and stiffness as well. Especially shear resistance provides stability for the horse while exercising and may affect the horse's balance (Murray et al., 2010b). Amendments of moisture have great impact especially on sand surfaces regarding stiffness, as well as energy restitution, deceleration and resonance frequency (Barrey et al., 1991, Ratzlaff et al., 1997). In accordance to our findings, Barrey et al. (1991) assumed sand to have a friction damping ability, which can be controlled over setting of the water content and moisture level. That is why abovementioned surface characteristics have to be payed special attention particularly when working with handicapped horses regarding previous injuries. Coming back to stiffness in particular, the VST noted significantly higher values on turf compared to sand, which is why Hypothesis 2 is supported as well. Again, generic declaration regarding better suitability of surfaces showing higher or less high stiffness must be determined on individual basis considering the horse's respective prehistory.

As especially moisture measurement, and thus proportionately grip and stiffness, is depending on daily weather conditions, a test series over a period of several days surely would have provided more meaningful results. The results presented above constitute a subjective but accurate snapshot. As already demonstrated in earlier studies (Peterson et al., 2012), finding the right moisture balance is a challenging issue, as especially weather influence can change moisture levels rapidly due to heavy rain or dry climate and also affect maintenance type and frequency.

Detailed analyzation of the experimental setup of the accelerometer study reveals a series of strengths and weaknesses. As today's state of the art allows a variety of technical as well as scientifical opportunities, the question arises as to why the focus has not been placed upon additional studies to ensure best possible training circumstances for our partner horse.
Previous accelerometer studies, aside from the low number of actually performed accelerometer studies (Barrey et al., 1991), did only include test setups with one accelerometer (Barrey and Galloux, 1997), most commonly placed in the area of the horse's sternum. Therefore, this study provides high benefits with regard to usage of more than one sensor, especially concerning accelerometer measurements at the distal limbs.
On the contrary fixing of the individual sensors proved to be rather difficult. Particularly the accelerometers placed on the saddle girth and the rider's belt, which were only taped, emerged as tolerably unsteady. Therefore, aforesaid sensors were only used as control values to define the subdivided phases of the jump sequences during this study. The accelerometers placed at the distal limbs turned out to be fixed more efficiently via tape and bandages but still couldn't assure outright secure stability. Consequently, accelerometer affixation providing higher stability should be reconsidered performing further studies. Barrey et al. (1991) fixed an accelerometer via plastic straps around the lateral hoof wall. Just as Hernlund et al. (2013) decided to fix accelerometers by a metal fixture, using a polyurethane hoof adhesive to fix the metal as well as to glue the accelerometer to the metal. These methods probably would have been a safer way regarding fixation, as their studies did not mention any conspicuities.
In addition, a study including more horses would also provide more conclusive results. Initially ten horses were envisaged to participate, as one horse dropped out due to health issues, the study was performed with nine horses over two consecutive days. The latter may have

influenced study results as well even though performing days were chosen with foresight regarding almost equal weather circumstances. On the contrary performing the study during the same day could have led to fatigue symptoms of the riders, which is why it was decided to carry out the study with more than just one rider. Sill, rider evaluation needs to be critically assessed, as two of the riders were professionals and two of them only amateurs. However, study outcome showed differences even between professional riders and their horses. Comparing Rider A and Rider B due to their horse's performance it is to be noted, that all horses ridden by Rider B didn't show any lead changes throughout the study at all, whereas Rider A's horses did perform a variety of lead changes just as the horses ridden by the amateur riders. This may simultaneously indicate a statement affecting professionality, which is substantiated by competition success track records, as Rider B demonstrably achieved greater successes during riding career so far, although both professionals compete within the same classes. Nevertheless, riders choice would have been just as difficult within professional classes, as every rider shows individual talent. Howsoever, direct impact of the riders on their horse's performance can be assumed. Outsourcing of rider's impact constitutes one of greatest difficulties regarding future studies and should be payed special attention.

To come back to lead changes and thereby leading and trailing forelimb, landing values unexpectedly showed different results concerning turf compared to sand surface (Fig. 34). Whereas grass surface provided rather visible differences comparing landing to take off, whereat landing showed higher values just as expected, the results within sand surface notably indicated even less differences and consistently similar results. As both surfaces did not show significant differences between leading and trailing forelimb during landing, while analyzation of turf surface almost cracked significance limits (1.26 +/- 1.74; $p=0.061$), Hypothesis 3 has to be rejected. As Hernlund et al. (2010) found TF to carry the highest loads during landing, our results differ in comparison, which may be caused by the higher amount of 64 horses participating Hernlund's study providing more conclusive and genuine results. Furthermore, different methods were used, since they did not use accelerometers, but high-speed video analyzations instead. Therefore, direct comparison of results may be difficult. Additionally, Hernlund used studs on turf, which may also lead to different results compared to simple shoeing on turf. On the contrary Hernlund et al. (2013) found no significant differences between maximum vertical deceleration of LF and TF during landing and take off using accelerometers, which can easier be compared to our results due to similar experimental setup and does also underpin our findings. The maximum range of horizontal deceleration and acceleration on the other hand showed higher values for LF compared to TF during take off as well as landing according to Hernlund et al. (2013). In conclusion similar results were found for both forelimbs at landing in accordance to our results.

Generally comparing mean values of take off and landing throughout the entire study, differences become apparent (Fig. 34). As higher forces are expected during landing as a logical consequence due to gravitational force, it can be assumed that higher acceleration values can be found during landing as well. As abovementioned results regarding take off and landing show significant differences only concerning LF on turf as well as sand, but not for TF on turf and sand, Hypothesis 4 is only confirmed for LF and has to be denied for TF. As Hernlund et al. (2010) found highest loads carried by TF during landing, which may be potential reason for our results, as higher forces are absorbed by the first limb to land, leading to less forces affecting the LF and therefore more unadulterated results. Gravitational forces may slightly falsify results for the TF, as they happen to be higher due to the TF's landing angle of roughly 90 degree just in accord with earlier findings by Clayton and Barlow (1991), as well as in compliance to Hernlund et al. (2013) showing TF to land in a steeper trajectory compared to LF.
Still, significant difference become apparent comparing surfaces when it comes to landing. Results of LF (0.98 +/-1.16; p=0.035) as well as TF (-0.84 +/-1.02; p=0.037) differ comparing surfaces against each other, furthermore significant results happen to be almost similar. As VST-data did show definite differences comparing both sand and grass surface, these differences have to affect the horses and their locomotor system as well as a logical consequence., which is why differences could have been already expected beforehand, especially considering landing with even higher forces having an effect.
Take off on the contrary did not show any differences, just as landing. Again, rather similar results for LF (0.48 +/-0.83; p=0.123) and TF (-0.60 +/-1.01; p=0.113) were highlighted, just as within landing.

When faced with AS representative to simple gallop strides, similar outcome was expected regarding acceleration values. Interestingly values did vary comparing LF and TF. As LF on grass showed higher values compared to TF on grass, proportionate related outcome was expected on sand. Even so sand surface showed higher acceleration values regarding TF than LF, which may be explained in conjunction with higher slipping on sand. The sliding phase of TF on sand may already lead to a higher force reduction and in addition to less forces affecting LF, which is substantiated by VST measurements as Arena I shows steadily higher force reduction values than Arena II (Fig. 25, Fig. 26). As mentioned above sand is more likely to give way against the hoof landing due to less shear resistance (Murray et al., 2010b), which is just in conformity with our results.

A closer look on each surface within itself reveals consistently different outcome. AS and DS were expected to provide rather similar results for both forelimbs, even so a variation range of differences is noted between LF and TF. As 58.3 % of compared pairs (Tab. 4) showed no significant differences, insignificance applies to most of the results. Still, 41.7 % indeed differed significantly, which is why Hypothesis 5 is only supported partially but not concerning the entirety of measurements. On this basis further data analyzation would have been necessary, especially to see, if influencing factors such as the day of performance or the rider did affect measurement results.

Additionally, reflecting on comparison within surfaces overall, further unexpected results were noted. Roughly equal outputs regarding LF and TF were anticipated within each surface, which could not be proved at large. Especially within sand surface and its homogeneity, adaptability and flexibility, more steady results and identical conditions were assumed for both forelimbs. As only 50 % of the test series showed insignificant differences between LF and TF, Hypothesis 7 has to be rejected for sand surface. Nevertheless, grass surface provided even more unsteady results with only 25 % of the results showing significant differences comparing LF and TF and 75 % differing insignificantly, leading to rejection of Hypothesis 7 for grass as well. It is to be interfered, therefore, that turf surfaces require even higher adaptability of the horses. Reasoning, the higher the surface's flexibility and adaptability to the horse's needs, the less the horses need to adapt themselves to it, which is why sand surfaces may be suitable to a higher number of horses than grass surfaces. Still, this doesn't mean sand is the general answer to the surface-question, as again, horses prehistory has to be included in considerations and deliberations as well.

Further assessing AS and DS, significant differences are noted comparing sand to turf throughout TTest, with only DS1 of the TL (-0.07 +/-0.38; p=0.619) being the exception (Tab. 3). Merging these outcomes with previously discussed comparison of AS (Fig. 33) leads to concluding Hypothesis 6 as partially correct. The majority of results showed higher values within turf compared to sand, which is also underpinned by higher grip and stiffness measured on turf as well as higher energy restitution and less force reduction and displacement (Fig. 17 – Fig. 28). As abovementioned regarding landing, VST-data substantiated aforesaid conclusions.

6. Conclusion

All the results of the study indicate presumed assumption of surface's impact on horses while training and jumping. In particular, but not limited, when it comes to the landing phase, ideal surface conditions are extremely important to ensure safety of the horse and continuity for the horse's health on the one hand, as well as prevent injuries on the other. As so many factors influence welfare of the horse, special attention has to be payed to eradicate as much negative influencing factors as possible to guarantee highest possible training and competing circumstances. Especially within competition and today's growth of better and better educated professional breeders breeding even better high-quality sport horses with the ability to perform in high class competitions all around the world, it has to be an obligation to invest as much time and effort, as was invested in breeding progress as a minimum. Welfare of the partner horse has to play a crucial leading role if maximum performance is expected in return. Therefore, further insight has to be gained providing best possible competition circumstances, such as surface conditions, by conducting further studies.

In any case, in order to give an example and inspire new ideas, this study should present another step towards achieving comprehensive knowledge and should encourage to further approaches. The strengths and weaknesses illustrated should provide valuable assistance to find even better-founded strategies throughout study performance.

Conclusively it can't be said, that a special surface fits the totality of horses better than the other. Throughout considerations, a horse's prehistory concerning health and health issues has to be included in surface, training and competing weighing. Relying on preliminary studies and collecting knowledge from all those study outcomes, will help to combine correctly what's best for the individual horse, as well as for the majority of horses trained or competed in respective facilities.

7. Summary in English

The intention to reduce injuries especially in high-performance sport horses provides impetus for further studies regarding extrinsic factors such as surface conditions. Therefore, the aim of the study was to characterise and compare the surfaces of equine arenas and relate these properties to the load on the jumping horse.

Nine middle-aged competition horses (9.45 years +/- 2.6) of different sex and breed with conventional steel shoeing had to overcome an obstacle (1.10 m) on both a sand and grass surface. The surfaces were analysed with the VST (Vienna Surface Tester) and VGT (Vienna Grip Tester). Horses and riders were equipped with four accelerometers (DELSYS) attached on the canon bone of the left and right forelimb on the saddle girth and the rider's lumbar spine (belt).

Grip test showed higher friction on grass (33.0±4.1 Nm) than on sand (16.7 ±1.67 Nm; p=0.005). VST indicated a significantly lower stiffness on sand (296.5 ±50.1 N/m) than on grass (553.8 ±137.2 N/m; p=0.0) surface. Particularly emphasising the horse's landing noted statistically significant differences between examined surfaces in leading limb (0.98 +/-1.158; p=0.035) as well as trailing limb (-0.84 +/-1.02; p=0.037). Whereas take-off did not show any significant differences, approach and departure motion cycles consequentially yielded a wide variation range throughout the study.

This work shows the influence of different surfaces to the musculoskeletal system of the horse. Different surfaces show verifiable impact on the horse's jump; this should be taken into account in training and competition to avoid injuries.

8. Zusammenfassung auf Deutsch

Ziel der Studie ist es, Training und Turnierteilnahmen für Sportpferde im Hochleistungssport sicherer gestalten zu können, indem die Einflüsse der Bodeneigenschaften auf den Bewegungsapparat des Pferdes untersucht werden. Dafür wurde unterschiedliche Reitplatzuntergründe auf ihre Eigenschaften untersucht, gegenübergestellt und verglichen.

Neun Turnierpferd mittleren Alters (9,45 Jahre +/- 2,6) unterschiedlichen Geschlechts und unterschiedlicher Rasse mussten einerseits auf einem Sandreitplatz und andererseits auf einem Reitplatz mit Wiesenuntergrund ein Hindernis der Höhe 1,10 m überwinden. Alle Pferde trugen konventionelle Rundeisen. Die beiden Reitplatzböden wurden vorab mittels VST (Vienna Surface Tester) und VGT (Vienna Grip Tester) auf ihre Eigenschaften hin untersucht. Für die Versuchsstudie der Pferde wurden sowohl Pferd als auch Reiter mit insgesamt vier Beschleunigungssensoren mit GPS-Funktion ausgestattet (DELSYS), um die Beschleunigungswerte zu ermitteln. Zwei Sensoren wurden jeweils am an den distalen lateralen Vordergliedmaßen angebracht (Röhrbein), ein weiterer Sensor wurde am Sattelgurt des Pferdes befestigt, der vierte Sensor am Gürtel des Reiters (im Bereich der Lendenwirbelsäule).

Die Grip-Messungen ergaben höhere Werte auf Gras- (33,0±4,1 Nm) als auf Sandboden (16,7 ±1,67 Nm; p=0,005). VST ergab statistisch signifikant geringere Werte für die Messung der Steifigkeit auf Sand (296,5 ±50,1 N/m) verglichen mit Gras (553,8 ±137,2 N/m; p=0,0).

Die Ergebnisse der EMG-Sensoren zeigten signifikante Unterschiede zwischen den beiden Reitplatzböden hinsichtlich führender (0,98 +/-1,158; p=0,035) und folgender (-0,84 +/-1,02; p=0,037) Vordergliedmaße. Die Landung nach dem Sprung zeigte keine signifikanten Unterschiede im Vergleich zu den Galoppsprüngen vor bzw. nach der Sprungphase, welche durchwegs unterschiedliche Ergebnisse lieferten.

Zusammenfassend zeigte die Studie nachweisbaren Einfluss auf den Sprung des Pferdes, der bei der zukünftigen Trainings- und Turnierplanung mit einbezogen werden sollte, um Verletzungen entgegenzuwirken und diesen bestmöglich vorzubeugen.

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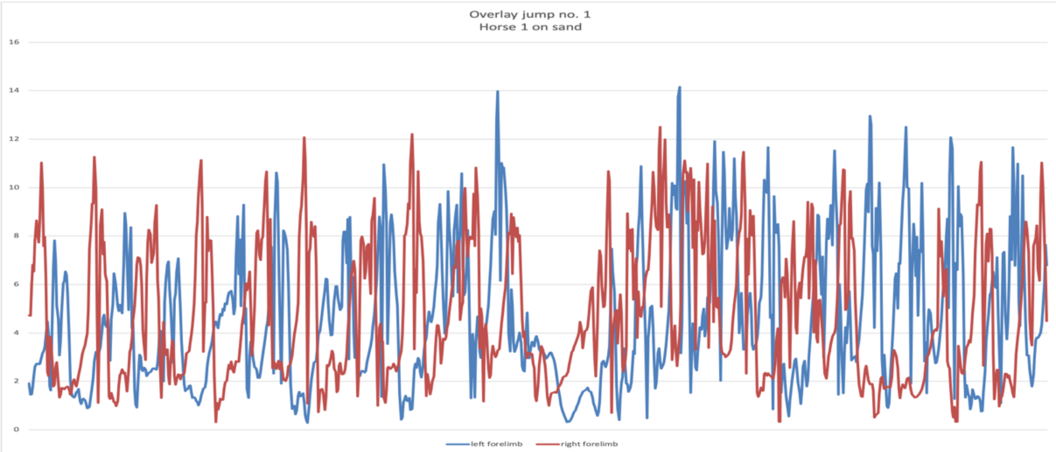
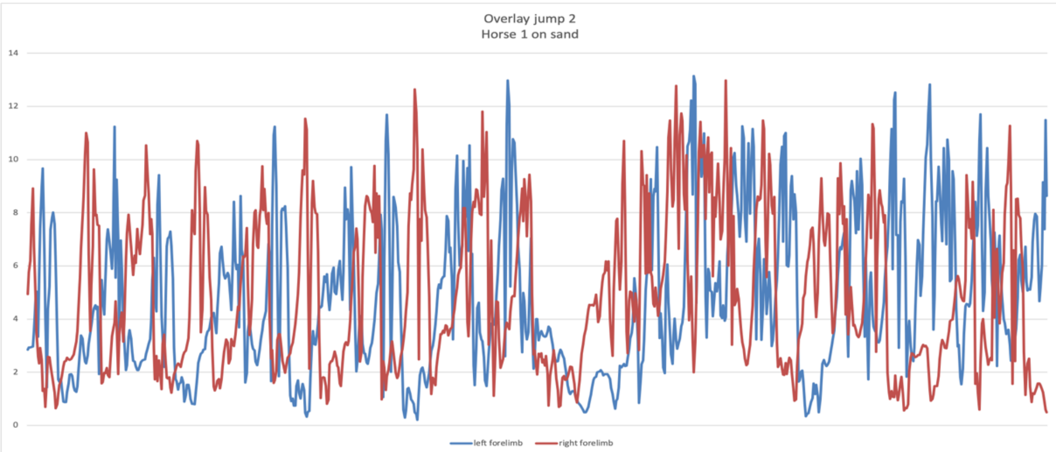
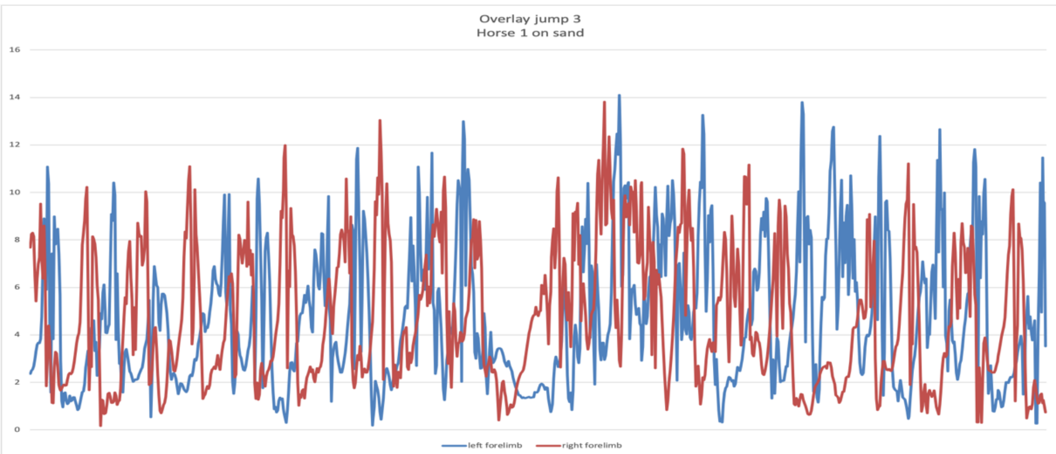
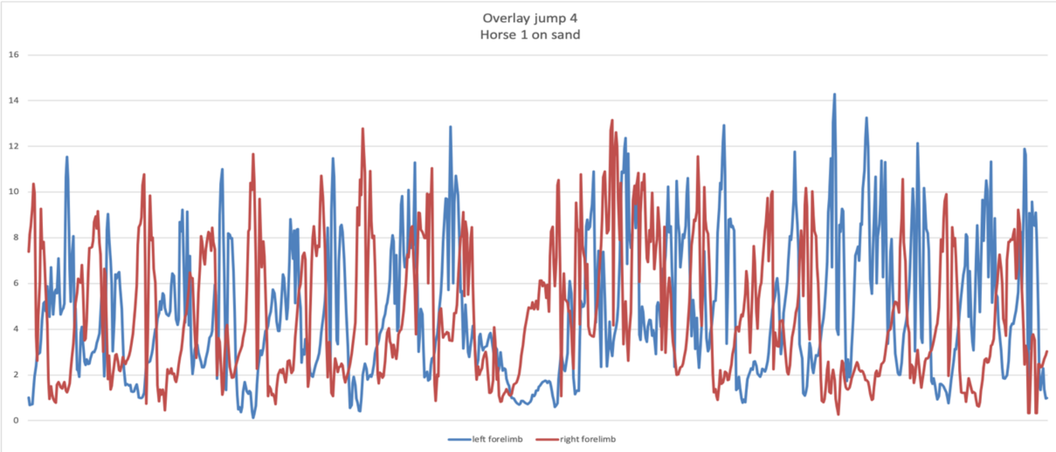
12. Appendix

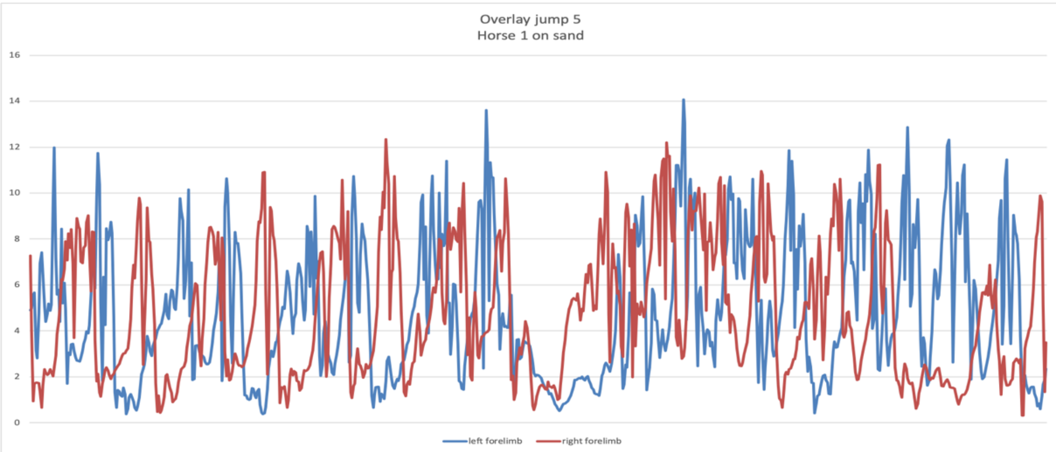
The following diagrams show total acceleration overlays of the left and right forelimb of all horses running through a jump sequence on sand and turf, measured with accelerometers in g (own research).








Overlay jump 4
Horse 1 on sand
16
14
12
10
8
6
4
2
0
left forelimb
right forelimb


Overlay jump 5
Horse 1 on sand
16
14
12
10
8
6
4
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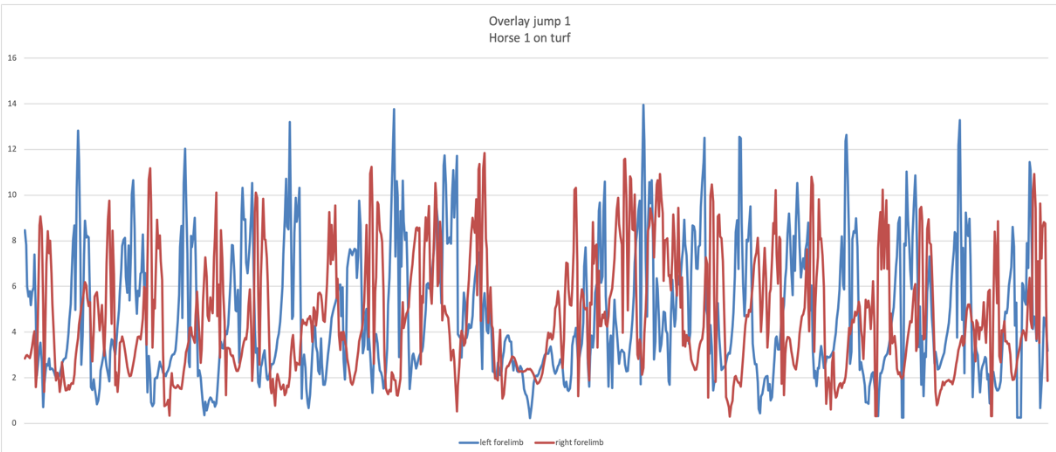
Overlay jump 1
Horse 1 on turf
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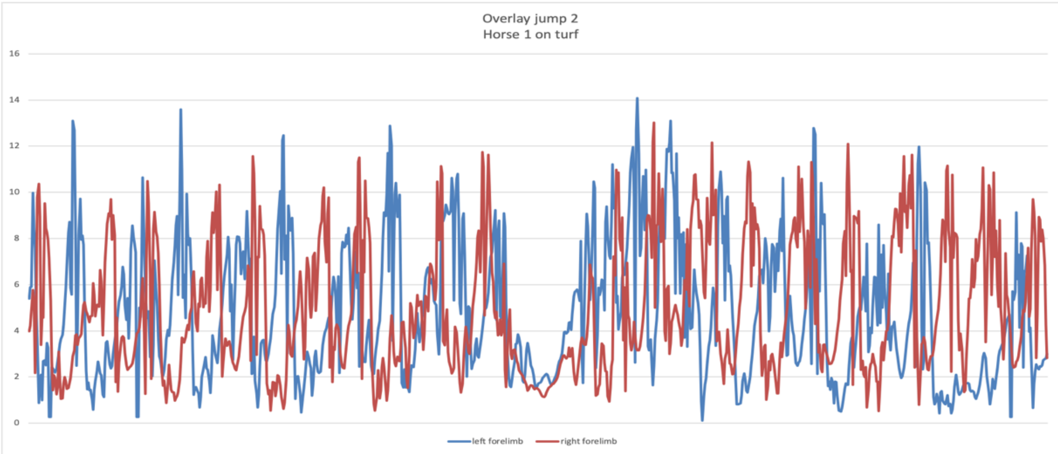
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Horse 1 on turf
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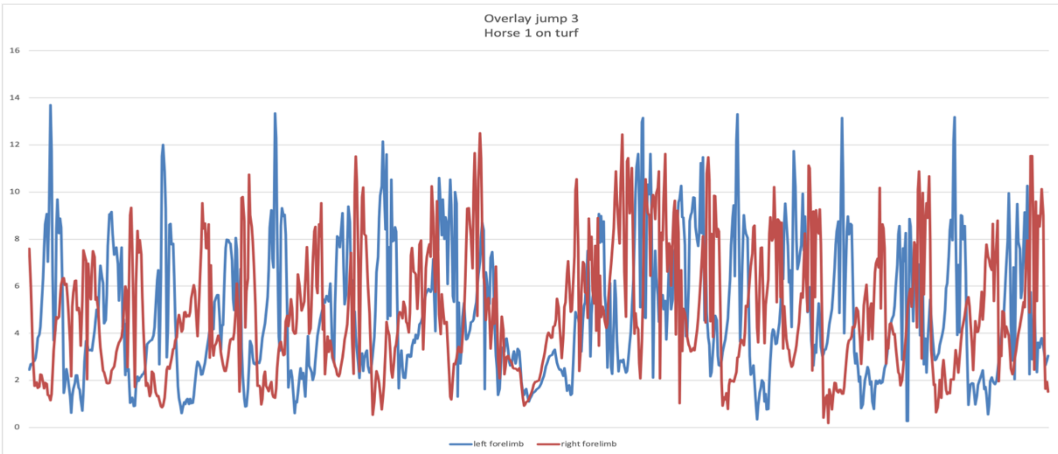
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Horse 1 on turf
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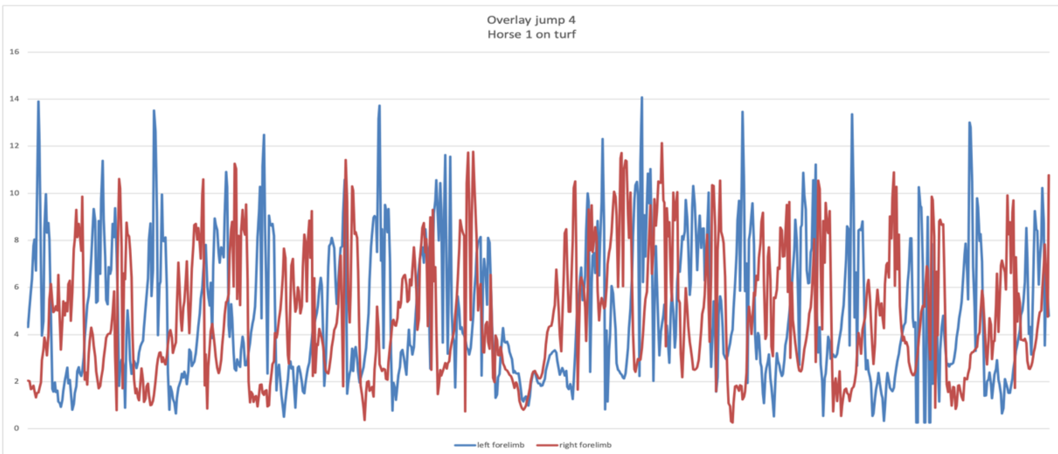
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Horse 1 on turf
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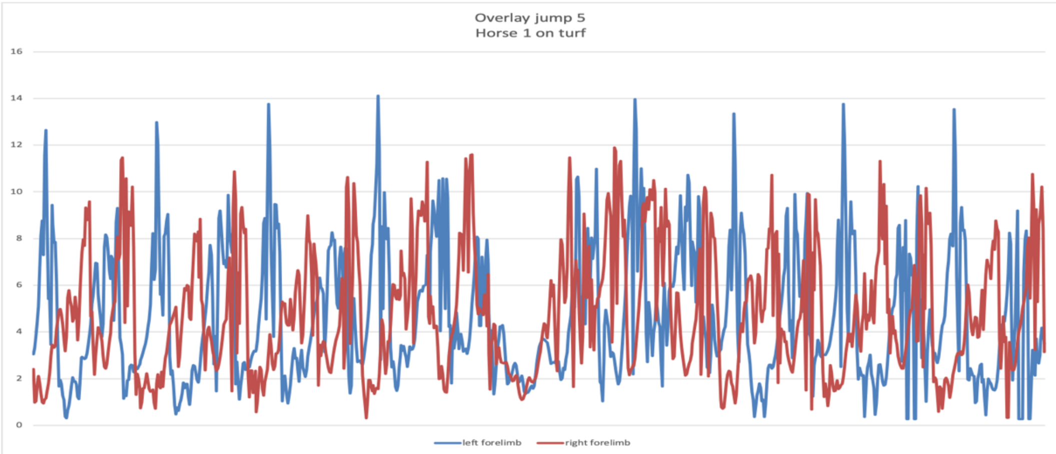
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Horse 1 on turf
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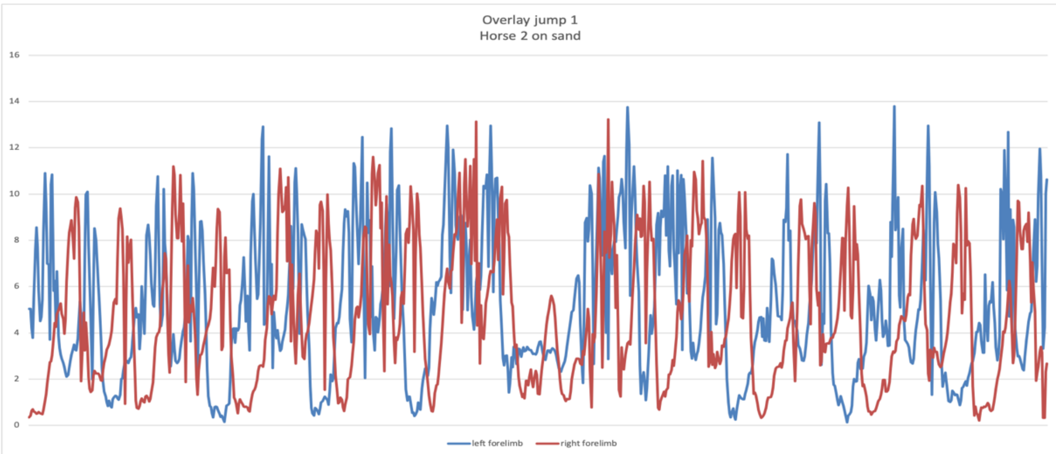
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Horse 2 on sand
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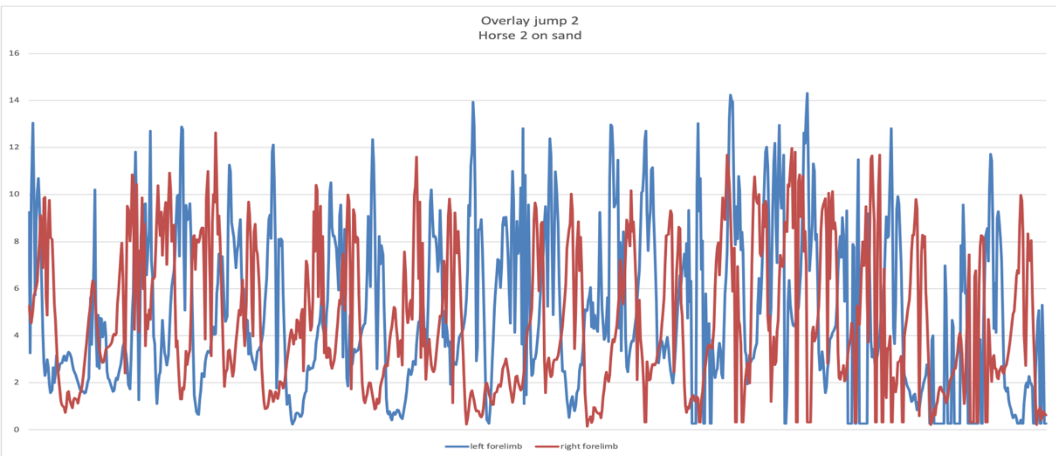
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Horse 2 on sand
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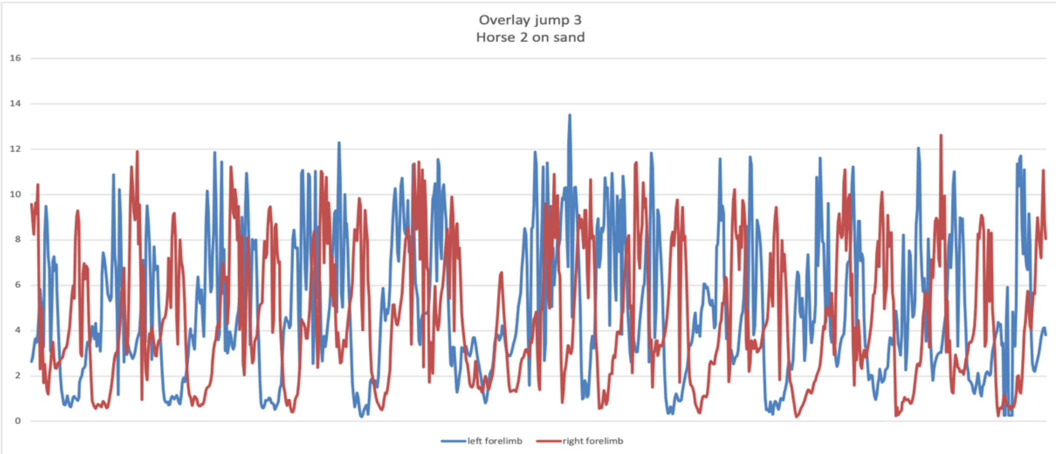
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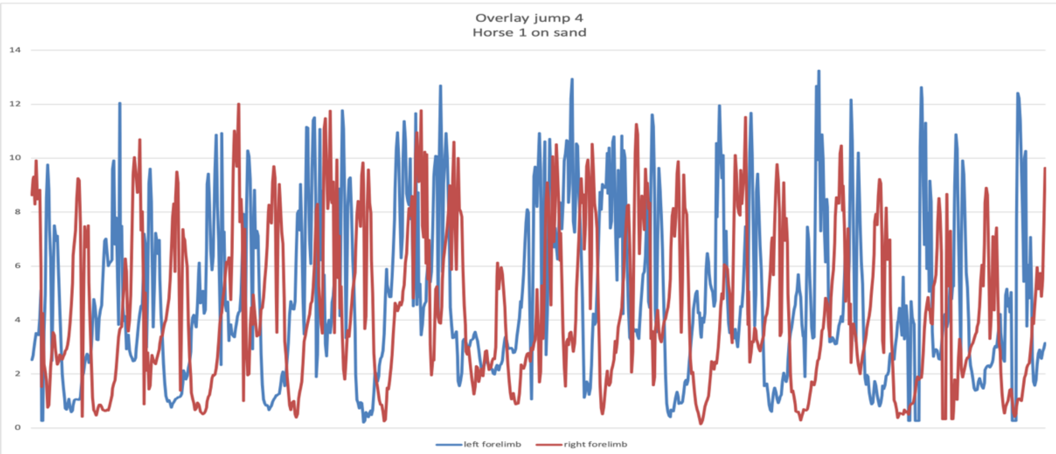
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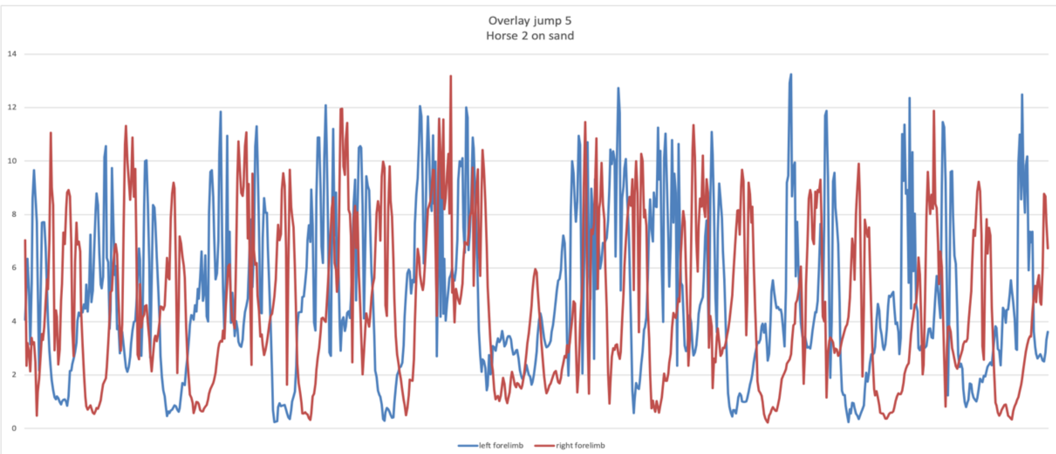
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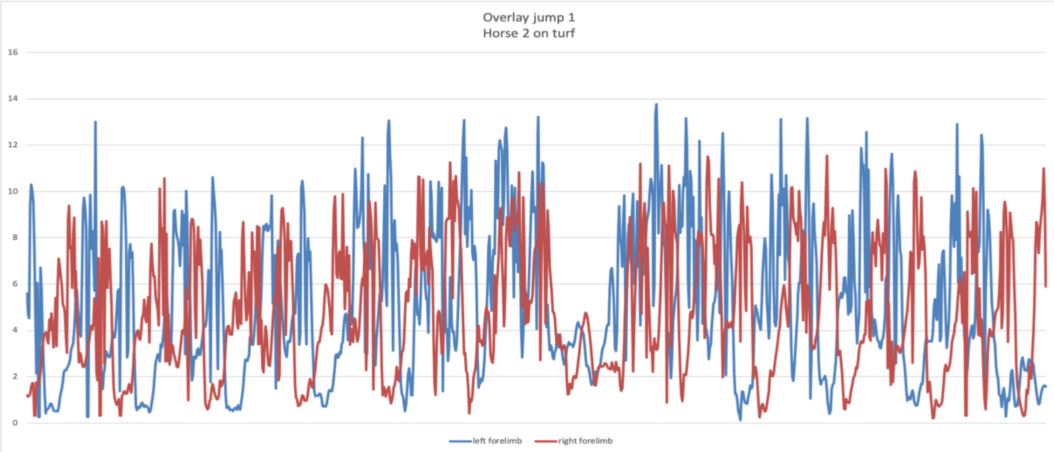
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Horse 2 on turf
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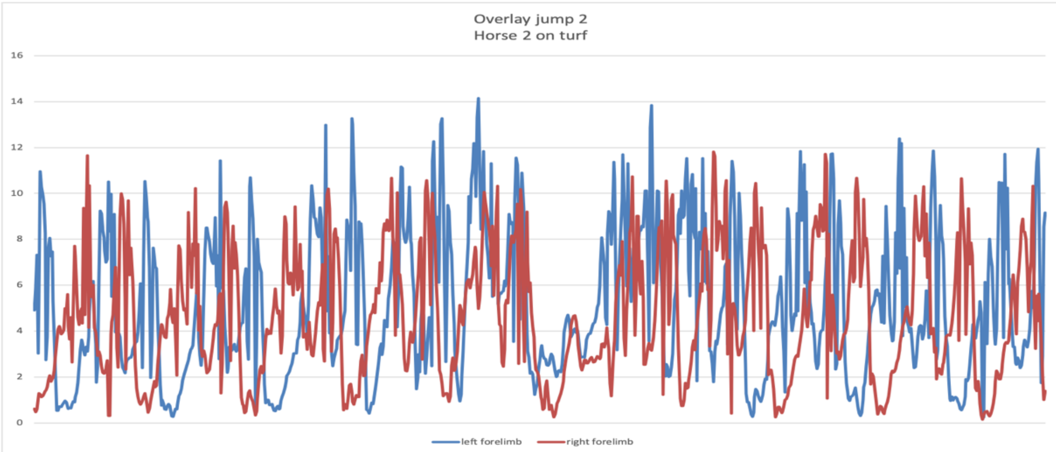
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Horse 2 on turf
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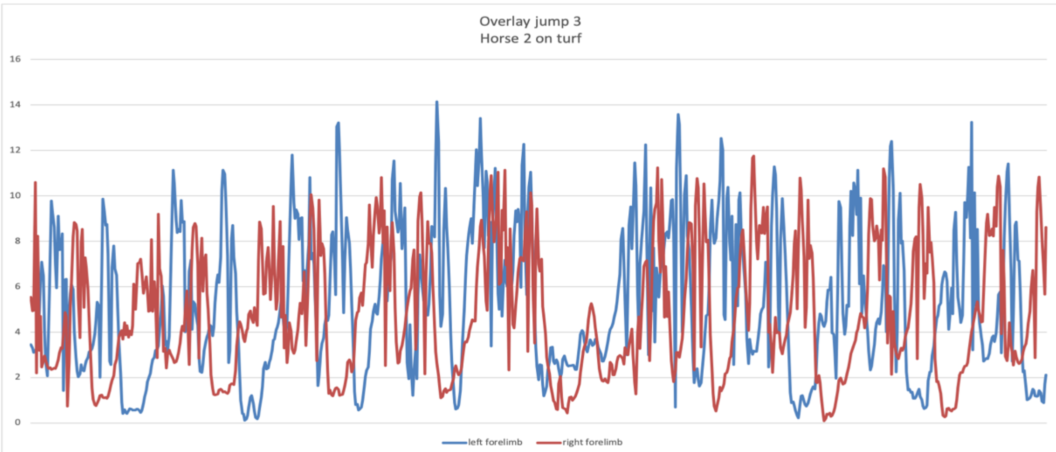
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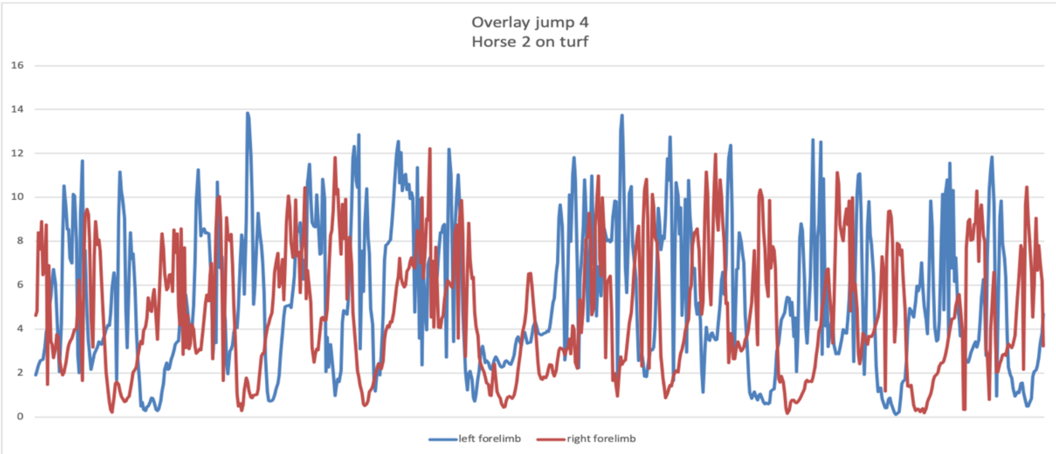
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Horse 2 on turf
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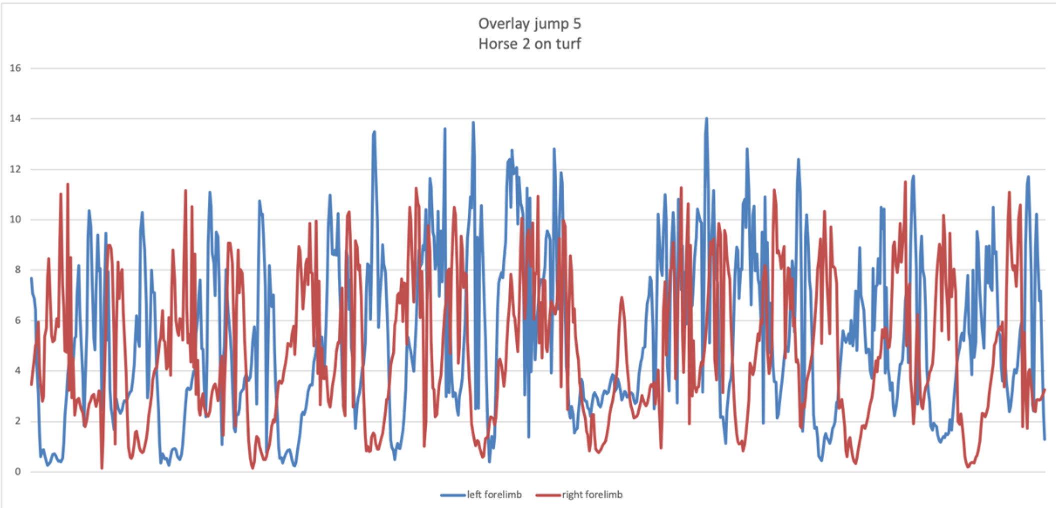
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Horse 2 on turf
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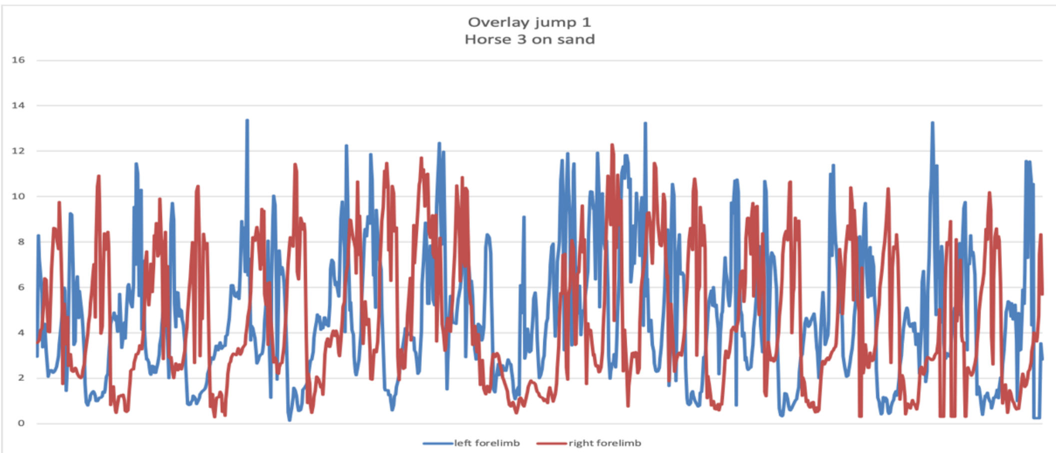
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Horse 3 on sand
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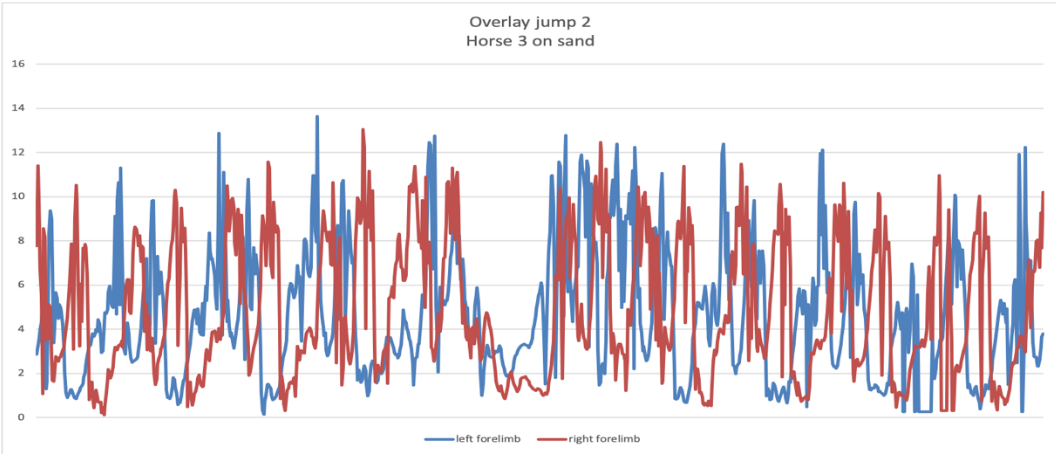

Overlay jump 2
Horse 3 on sand
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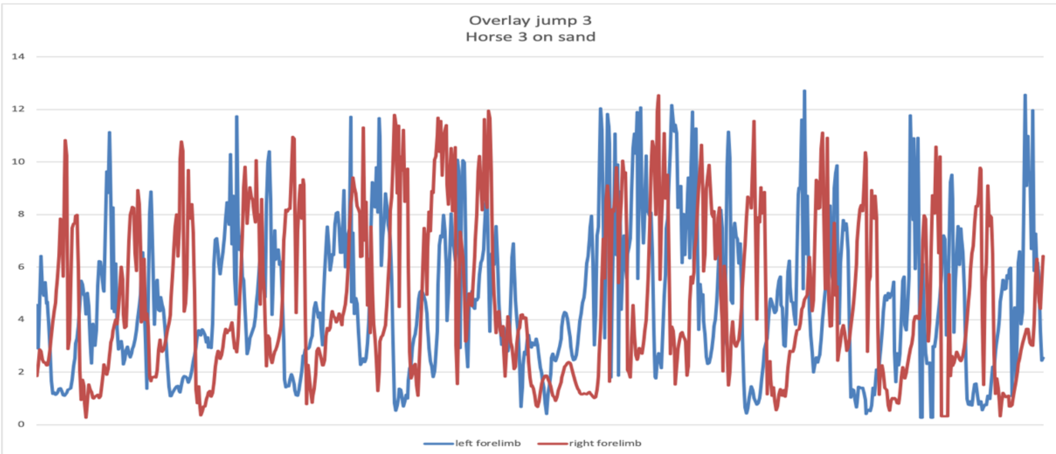

Overlay jump 3
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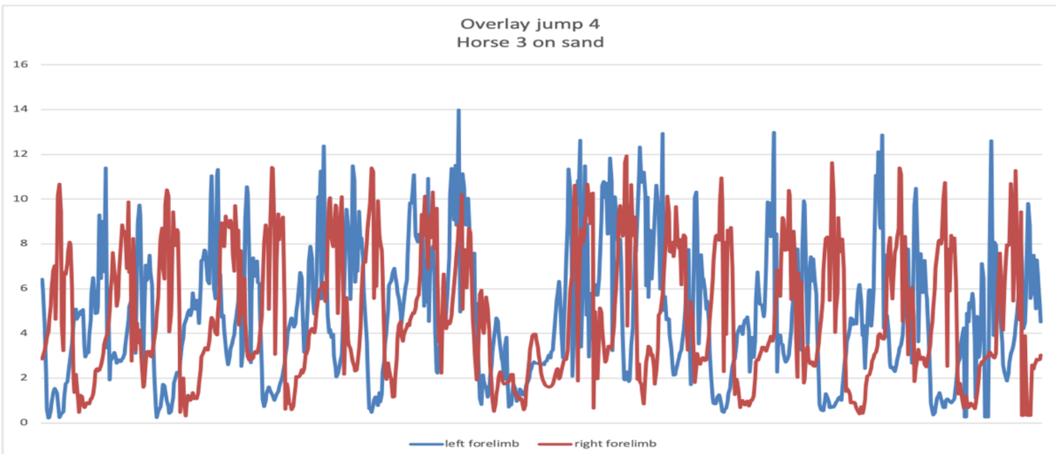

Overlay jump 4
Horse 3 on sand
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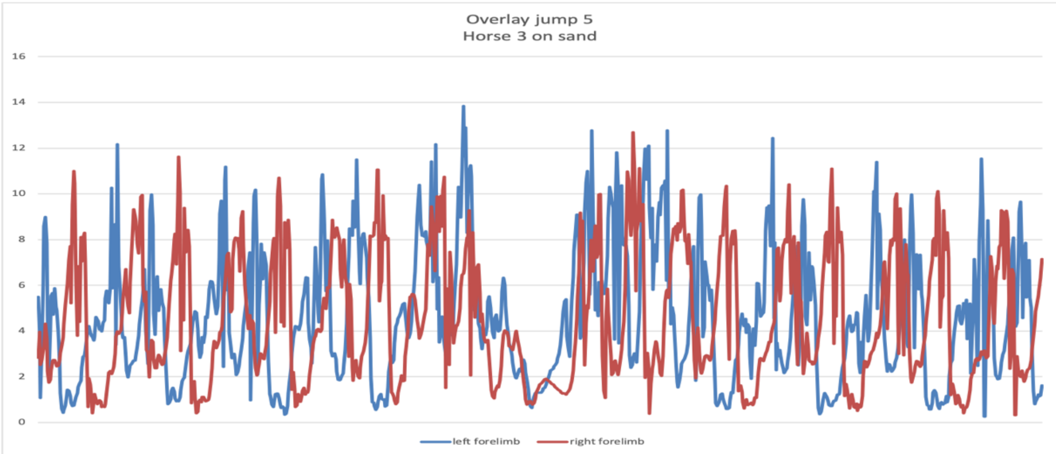
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Horse 3 on sand
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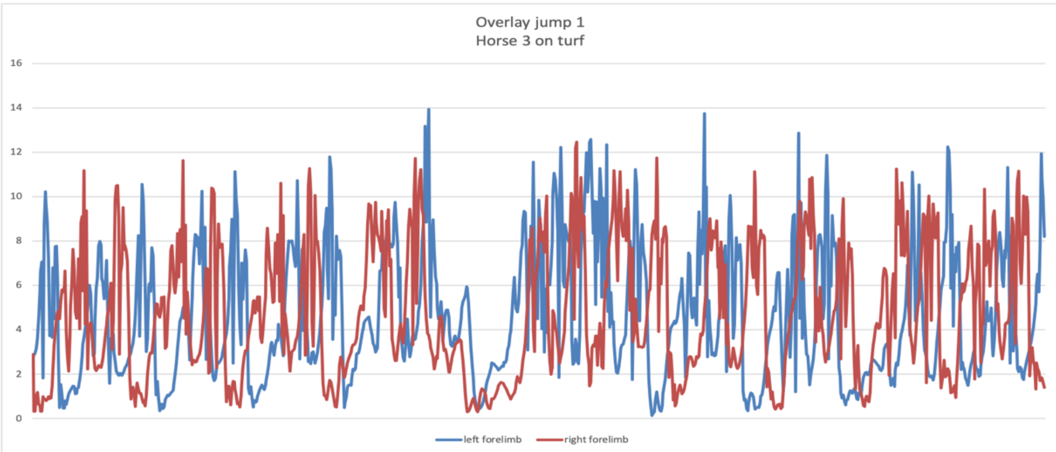
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Horse 3 on turf
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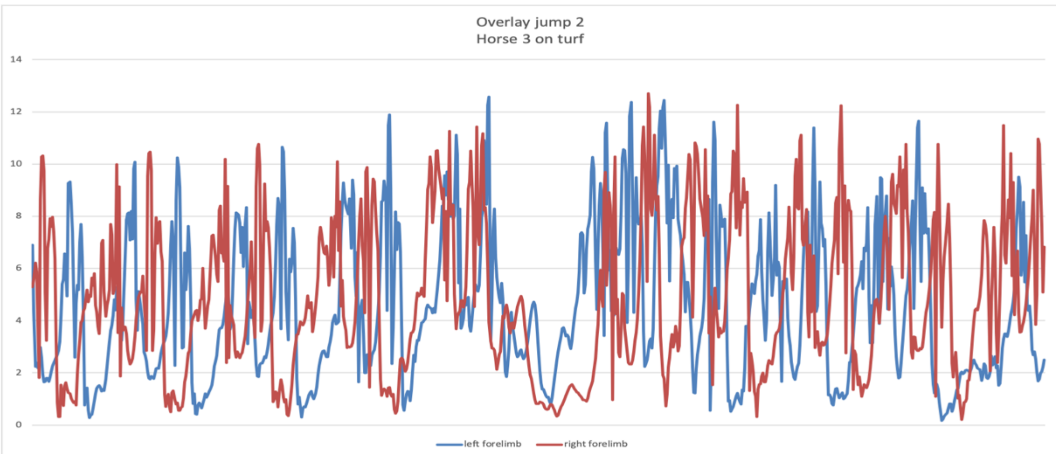
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Horse 3 on turf
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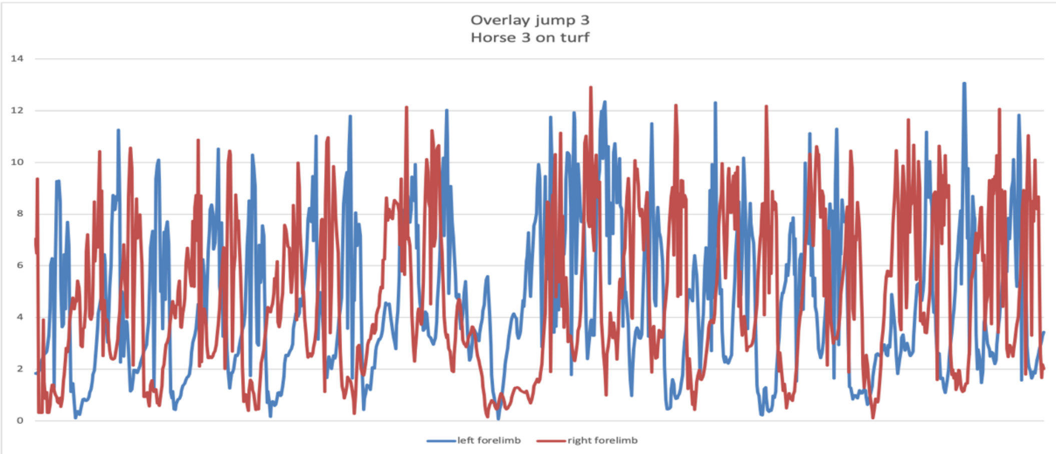

Overlay jump 3
Horse 3 on turf
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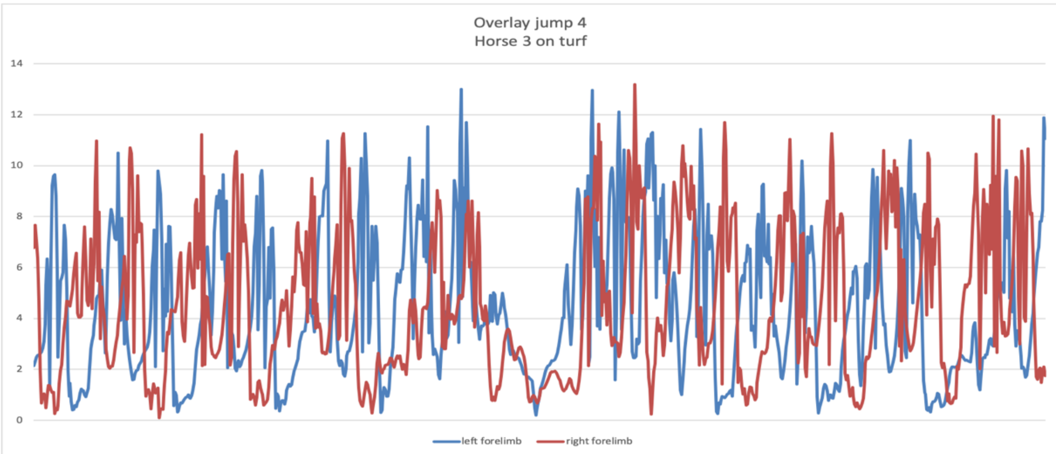

Overlay jump 4
Horse 3 on turf
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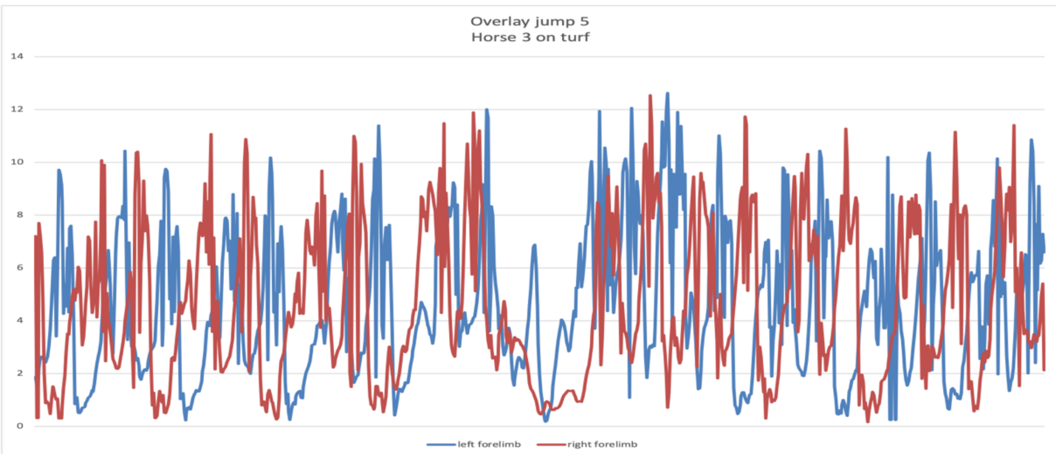

Overlay jump 5
Horse 3 on turf
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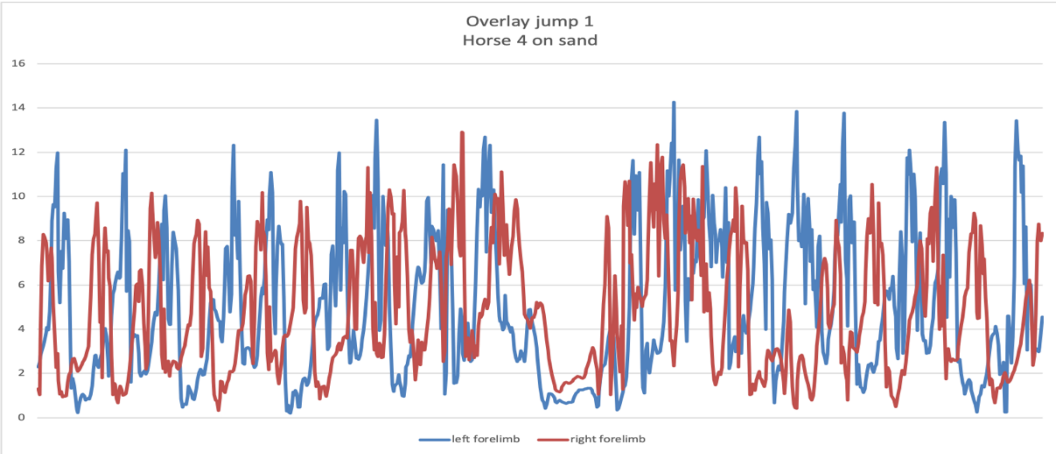
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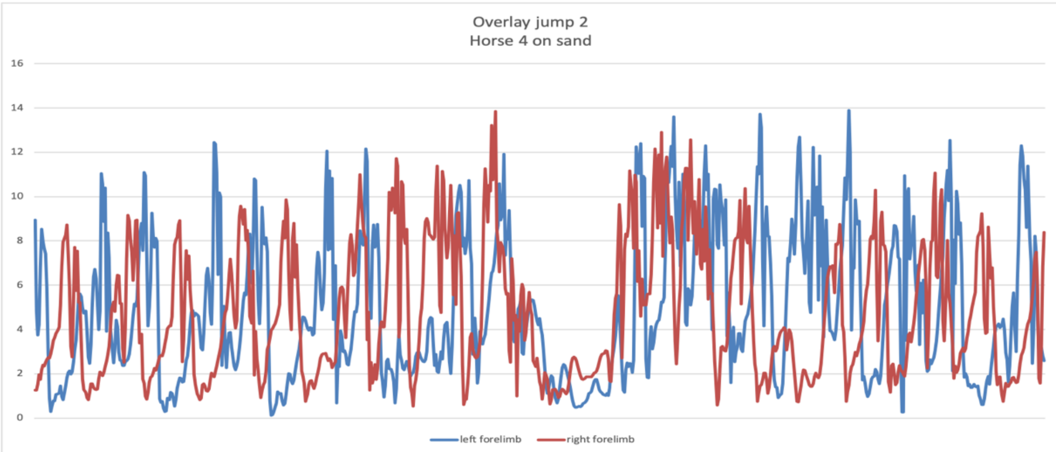
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Horse 4 on sand
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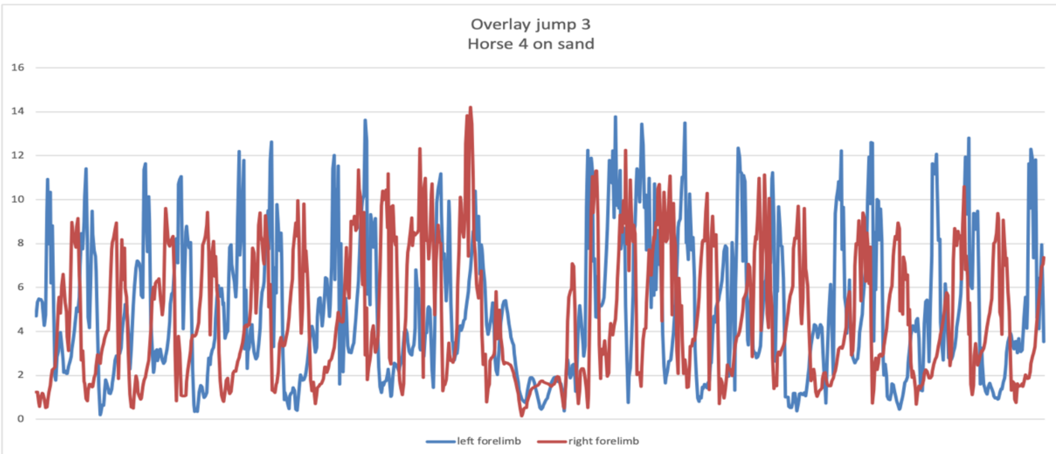
Overlay jump 3
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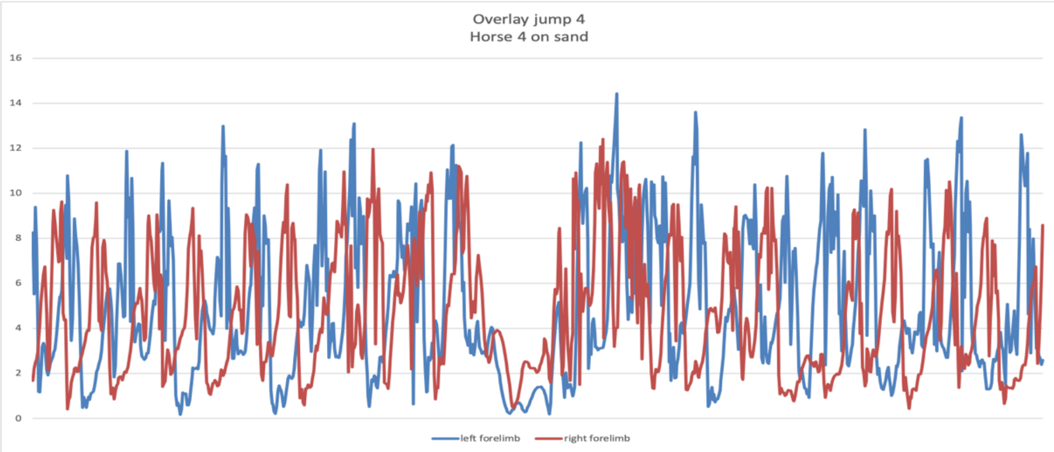
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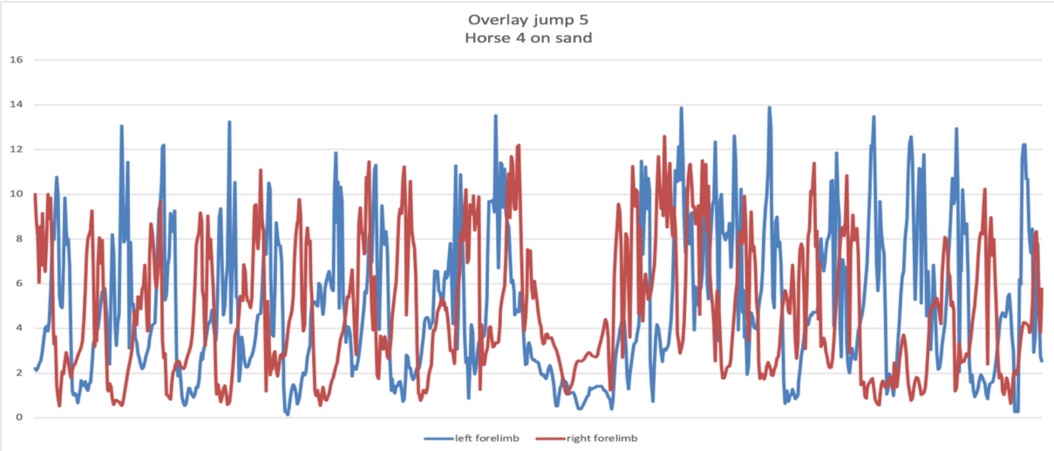
Overlay jump 5
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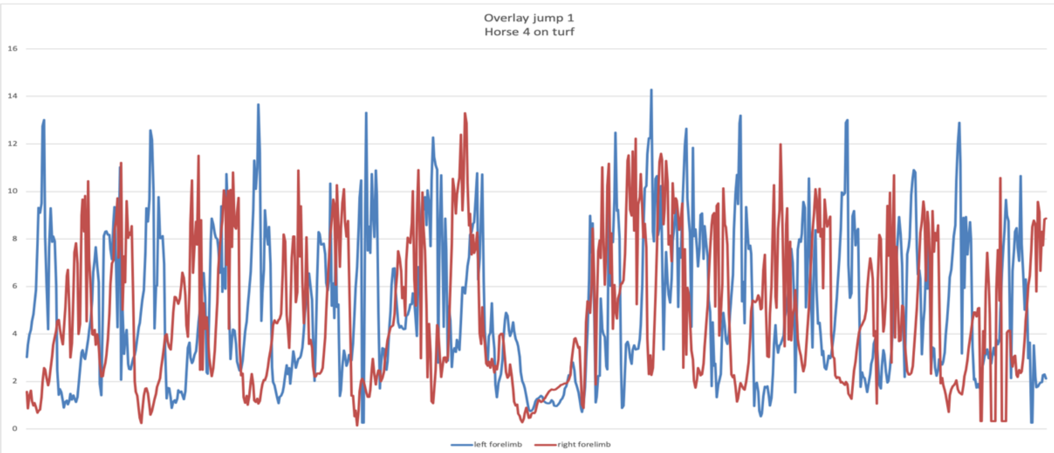
Overlay jump 1
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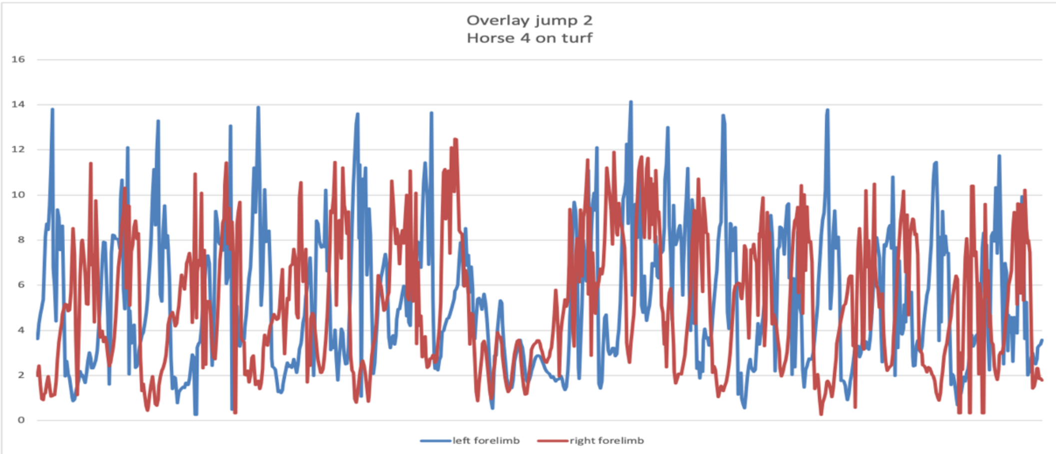
Overlay jump 2
Horse 4 on turf
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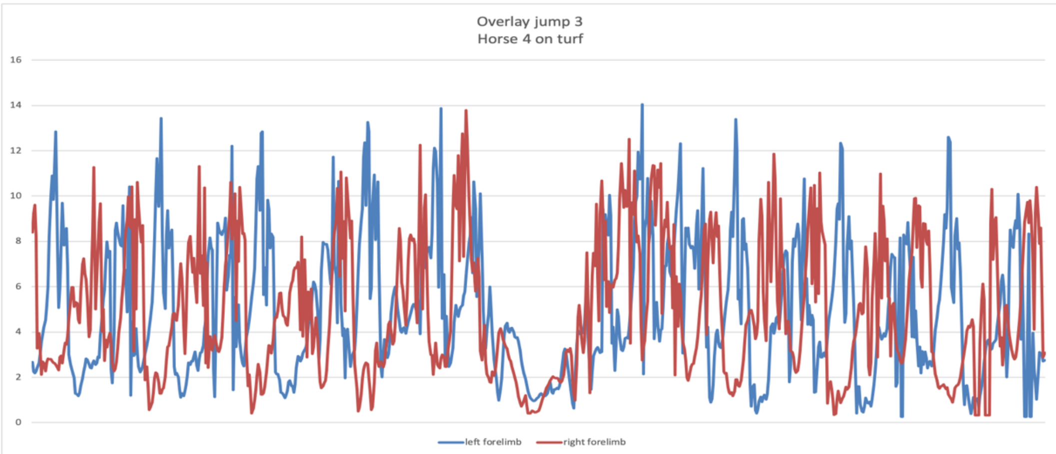
Overlay jump 3
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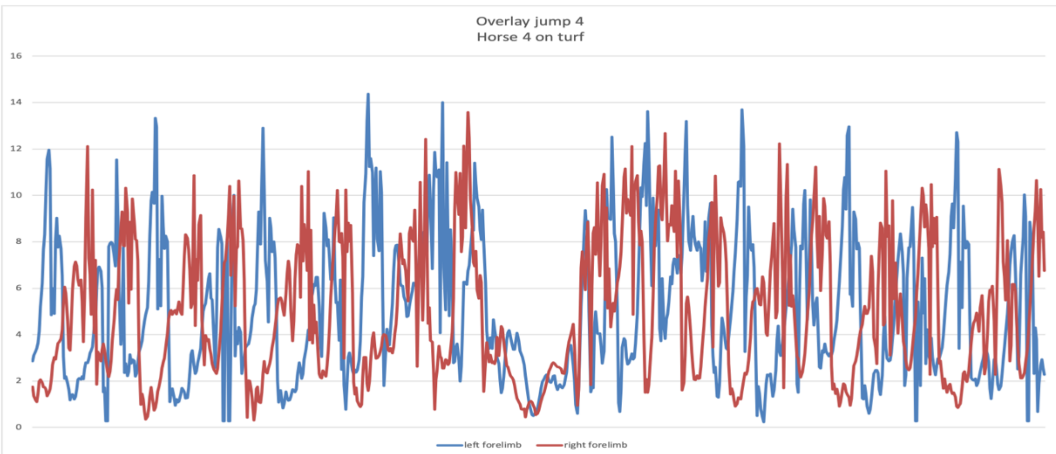
Overlay jump 4
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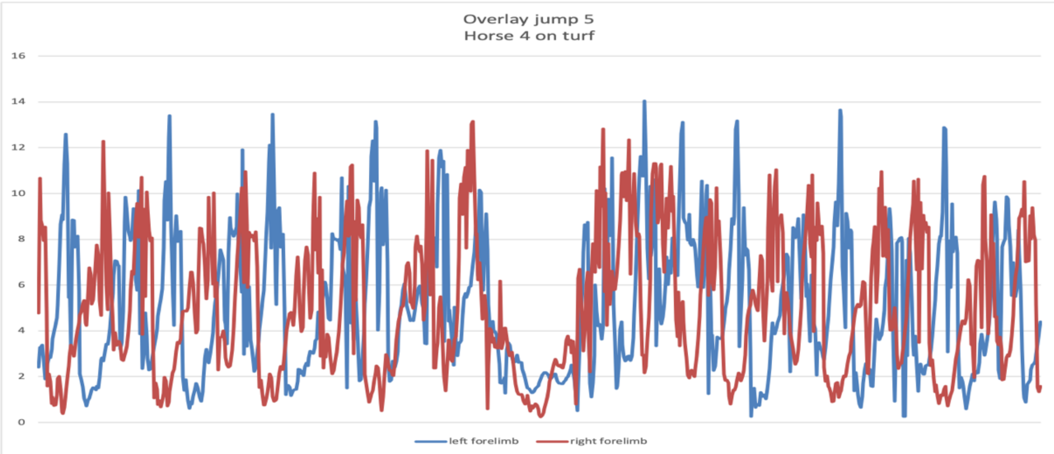
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Horse 4 on turf
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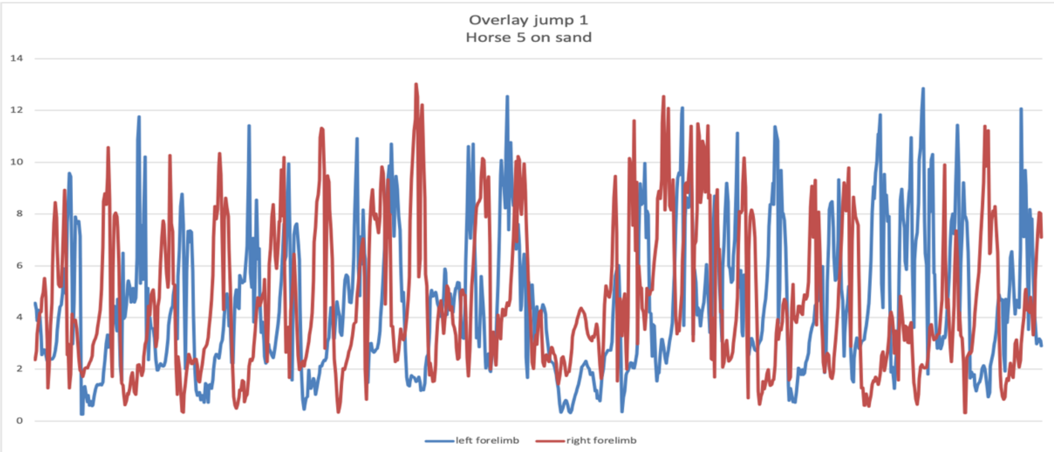
Overlay jump 1
Horse 5 on sand
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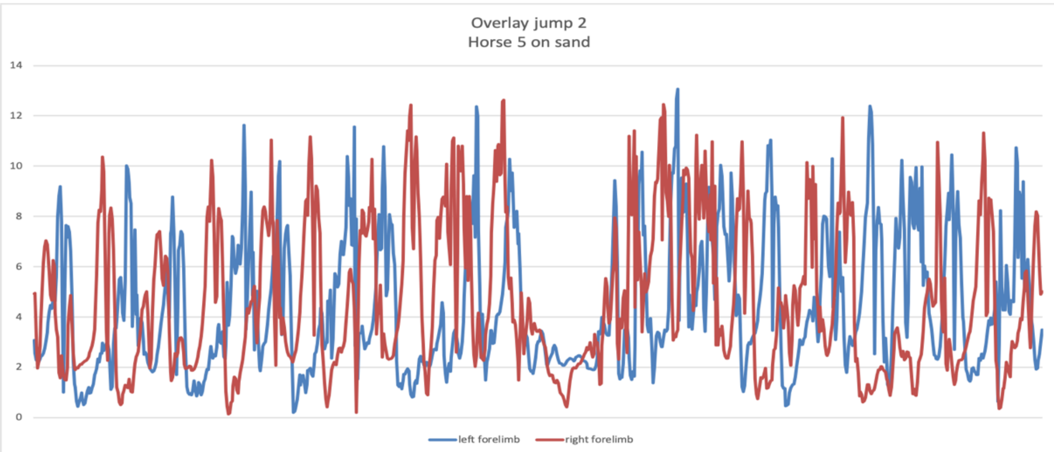
Overlay jump 2
Horse 5 on sand
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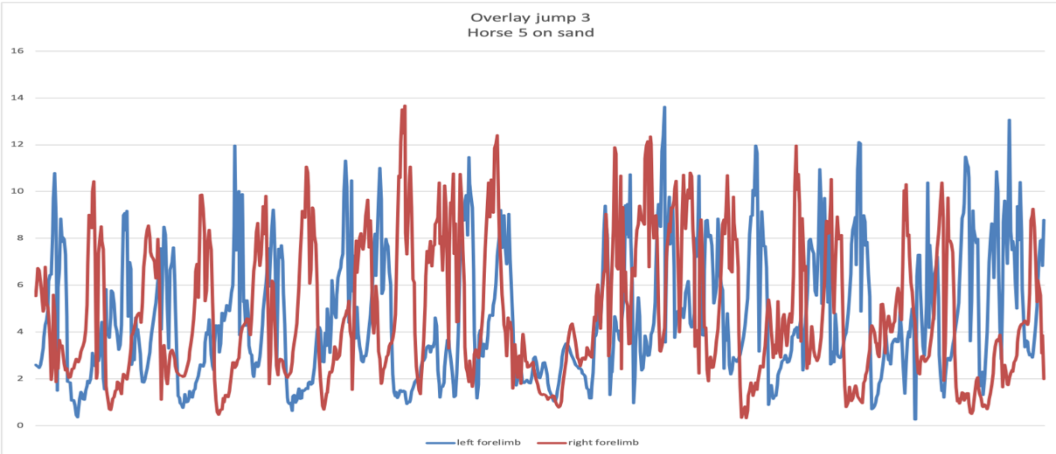
Overlay jump 3
Horse 5 on sand
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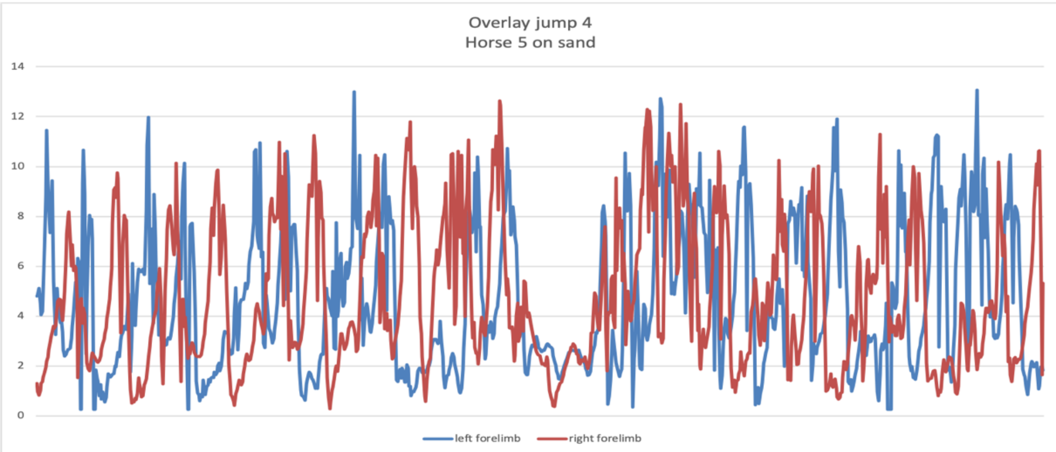
Overlay jump 4
Horse 5 on sand
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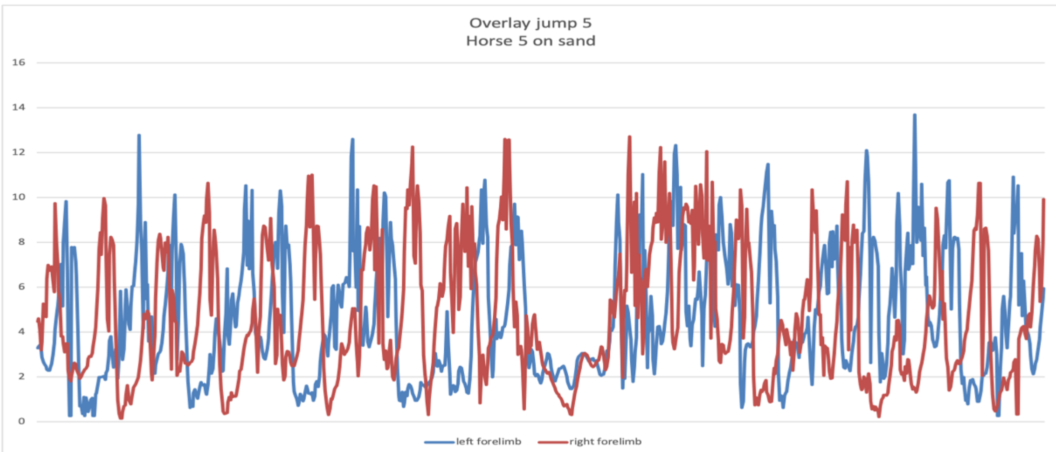
Overlay jump 5
Horse 5 on sand
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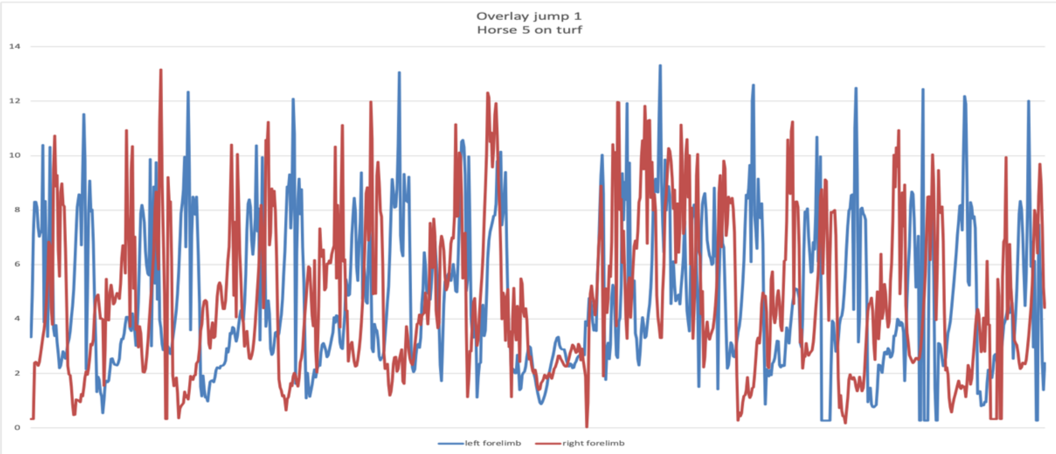
Overlay jump 1
Horse 5 on turf
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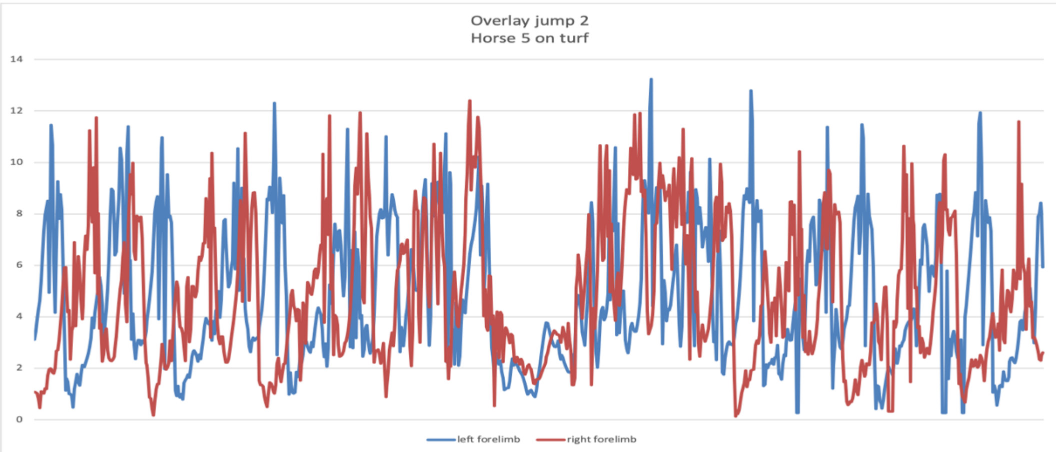
Overlay jump 2
Horse 5 on turf
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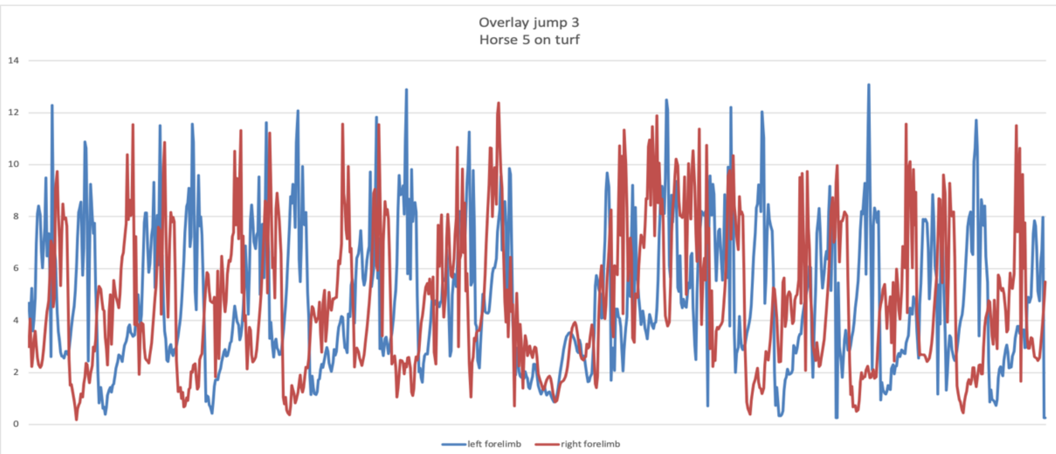
Overlay jump 3
Horse 5 on turf
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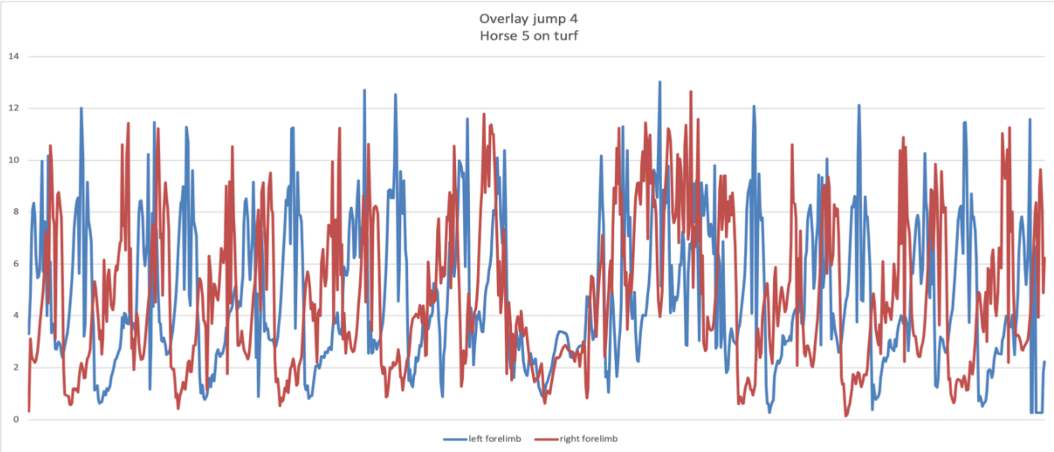
Overlay jump 4
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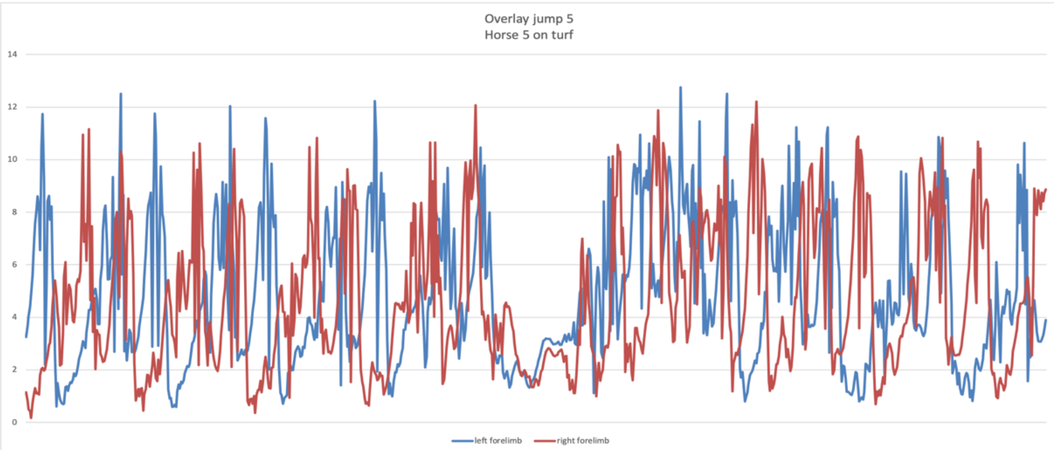
Overlay jump 5
Horse 5 on turf
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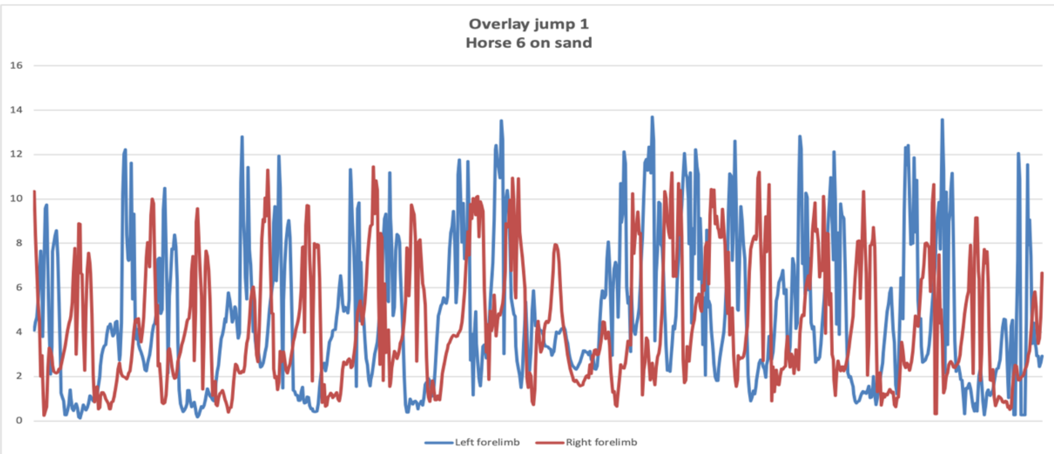
Overlay jump 1
Horse 6 on sand
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Left forelimb
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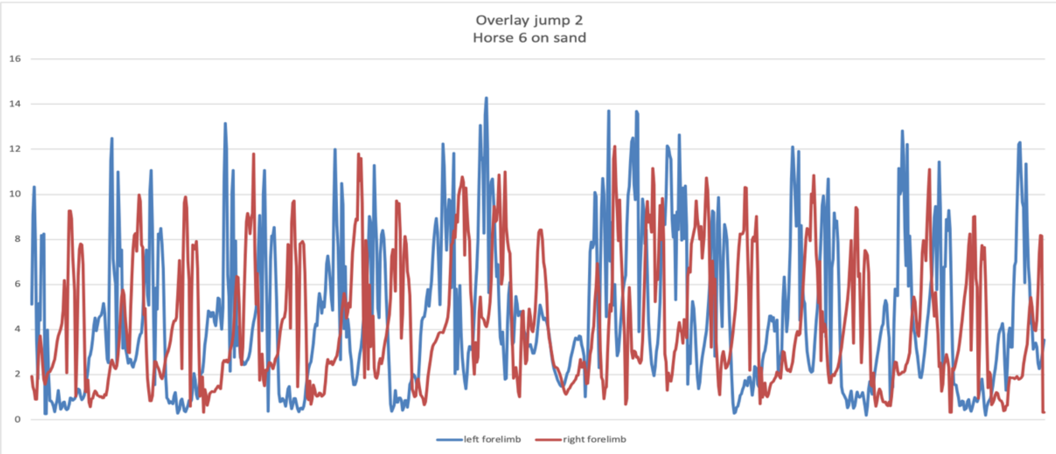
Overlay jump 2
Horse 6 on sand
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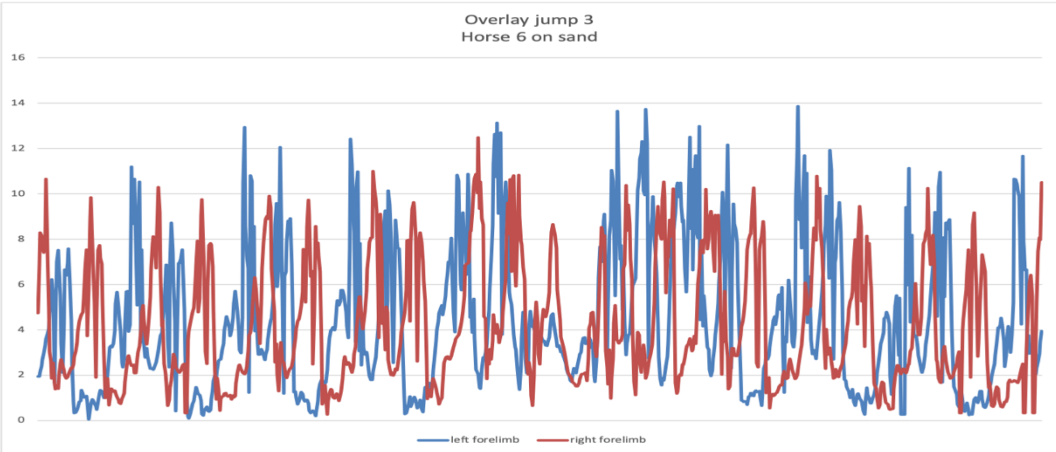
Overlay jump 3
Horse 6 on sand
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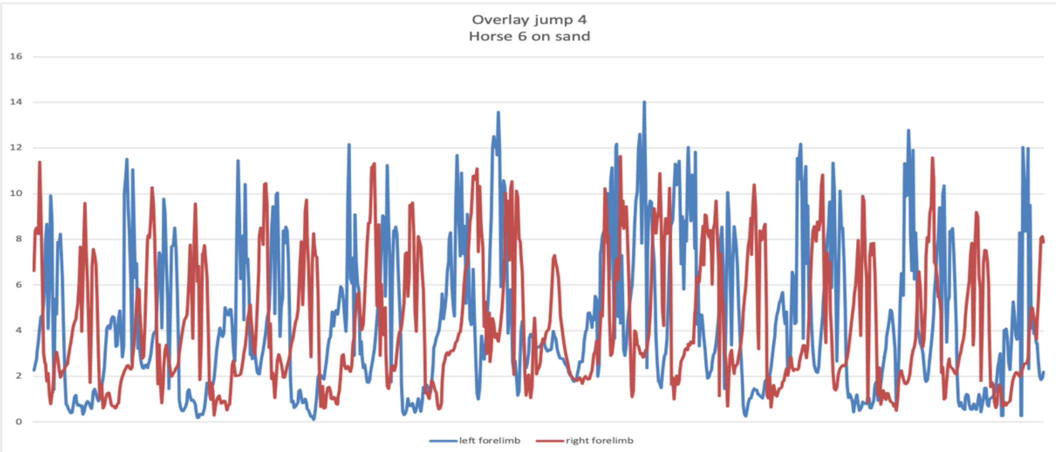
Overlay jump 4
Horse 6 on sand
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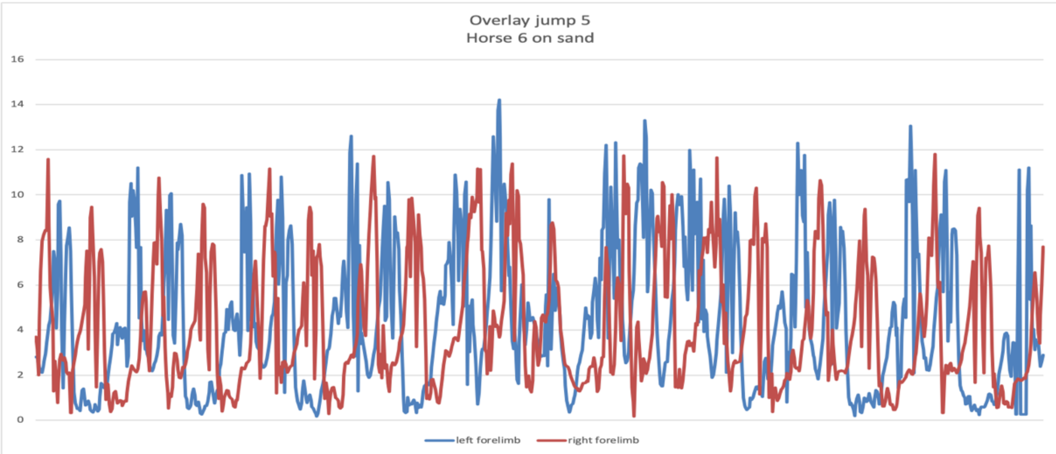
Overlay jump 5
Horse 6 on sand
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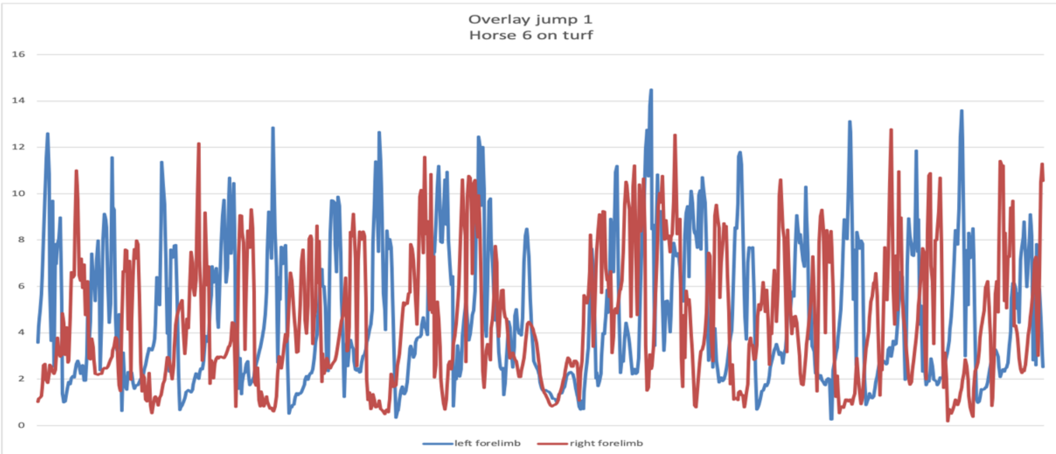
Overlay jump 1
Horse 6 on turf
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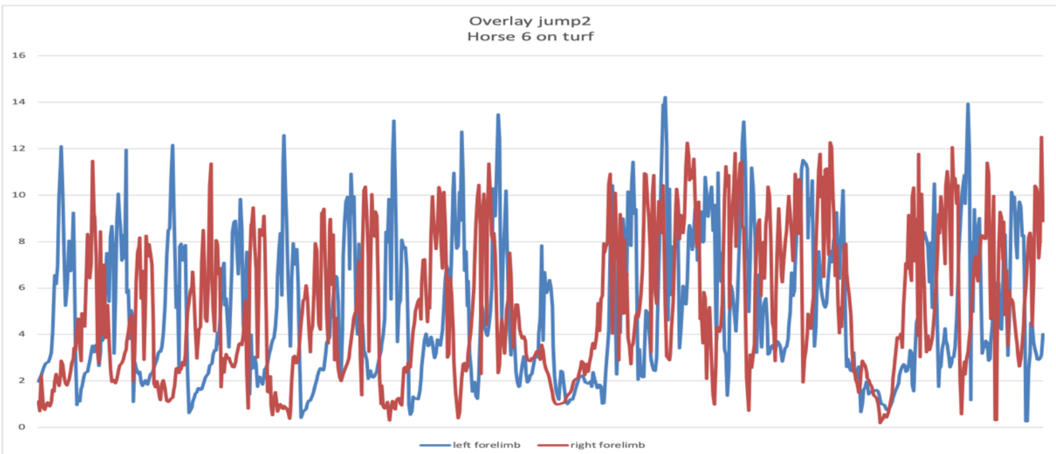
Overlay jump2
Horse 6 on turf
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right forelimb

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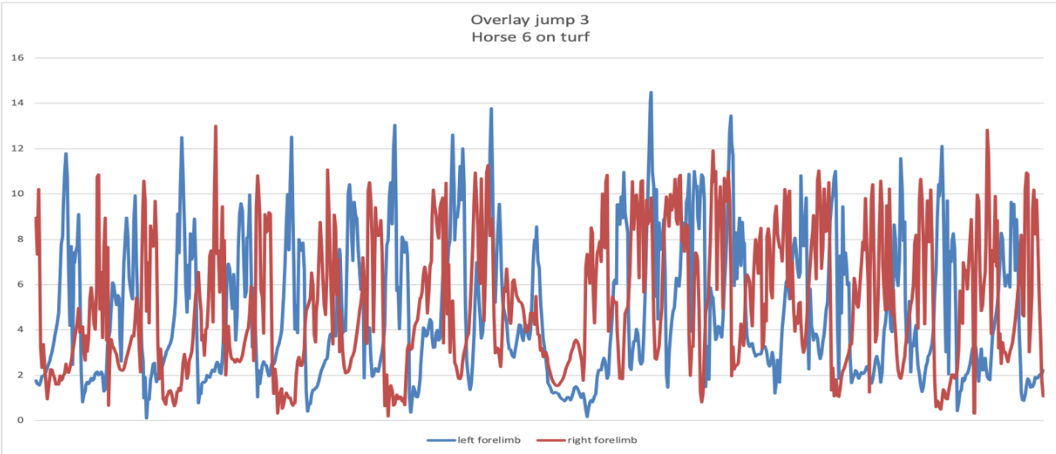
Overlay jump 3
Horse 6 on turf
16
14
12
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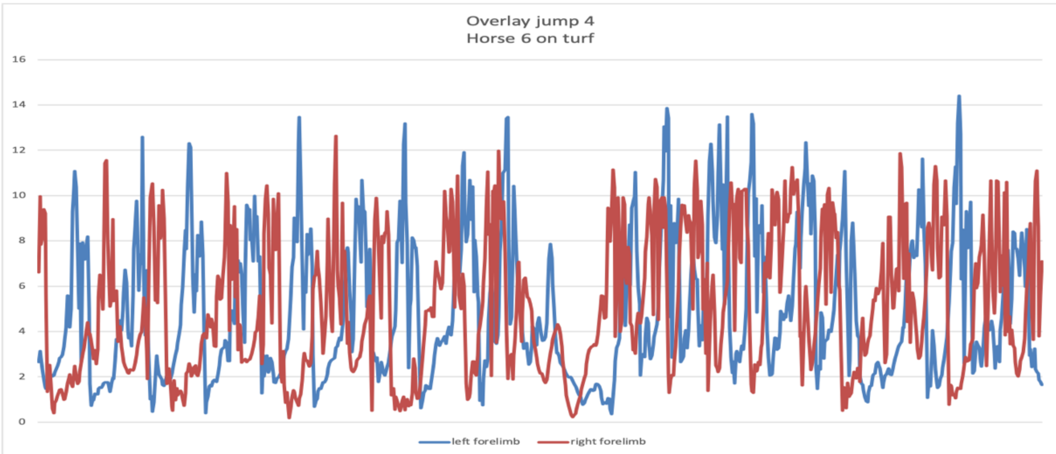
left forelimb
right forelimb


Overlay jump 4
Horse 6 on turf
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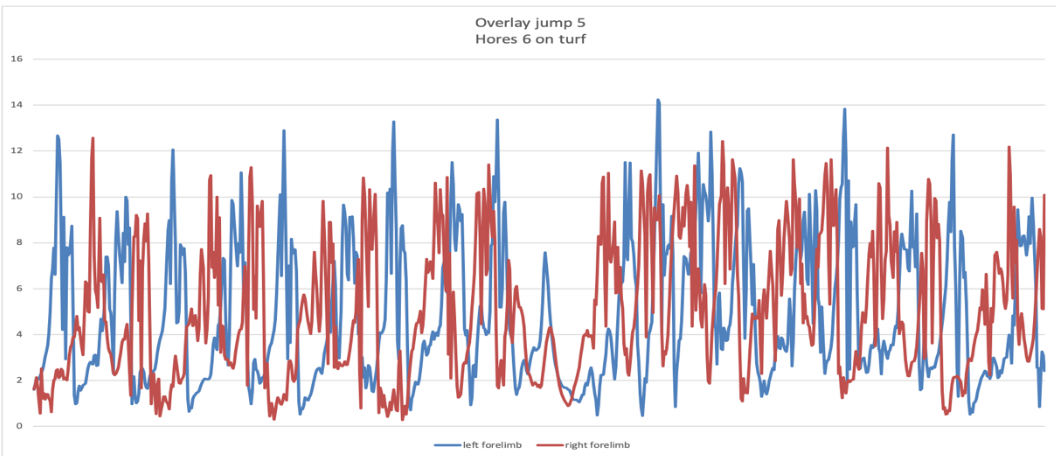
right forelimb


Overlay jump 5
Hores 6 on turf
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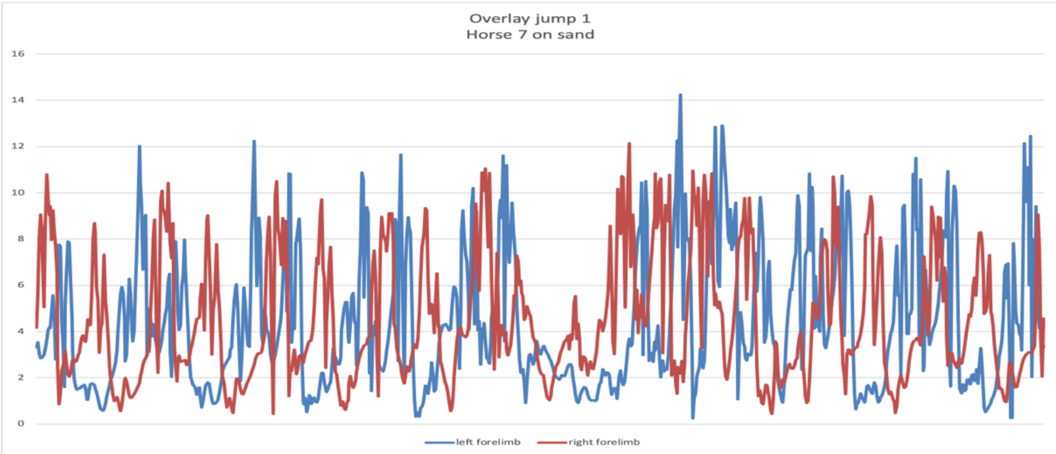
right forelimb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Horse 7 on sand
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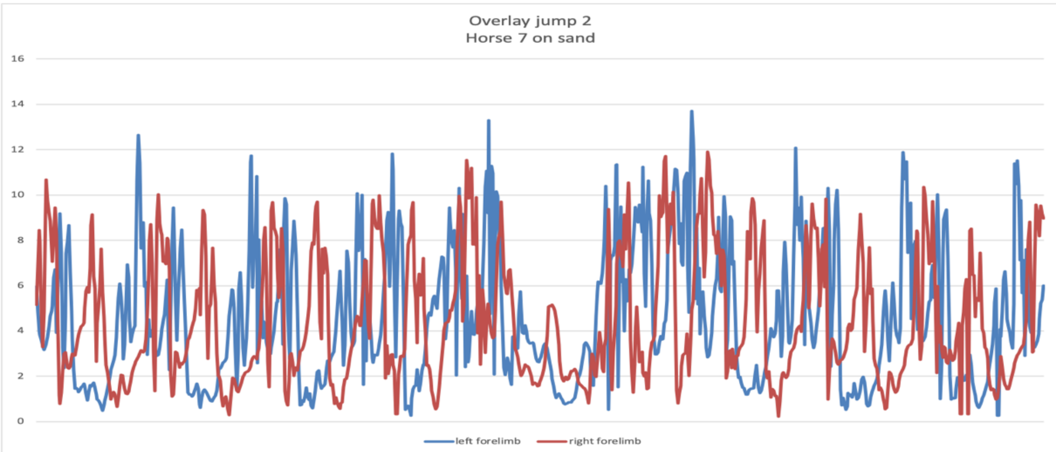
right forelimb


Overlay jump 2
Horse 7 on sand
16
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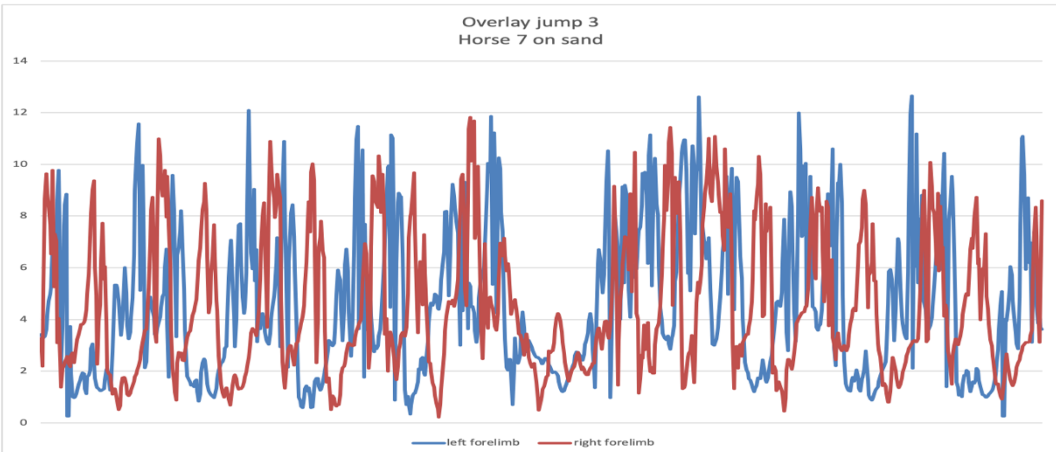
right forelimb


Overlay jump 3
Horse 7 on sand
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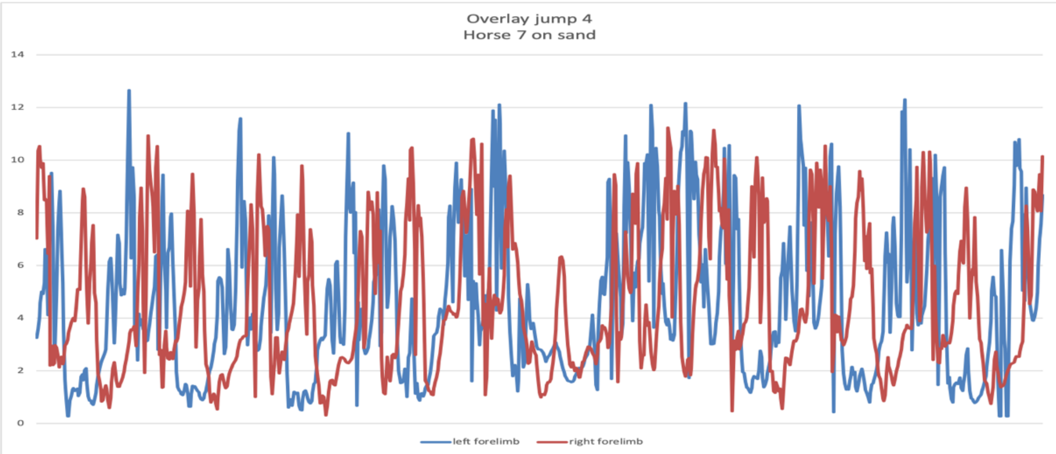
right forelimb


Overlay jump 4
Horse 7 on sand
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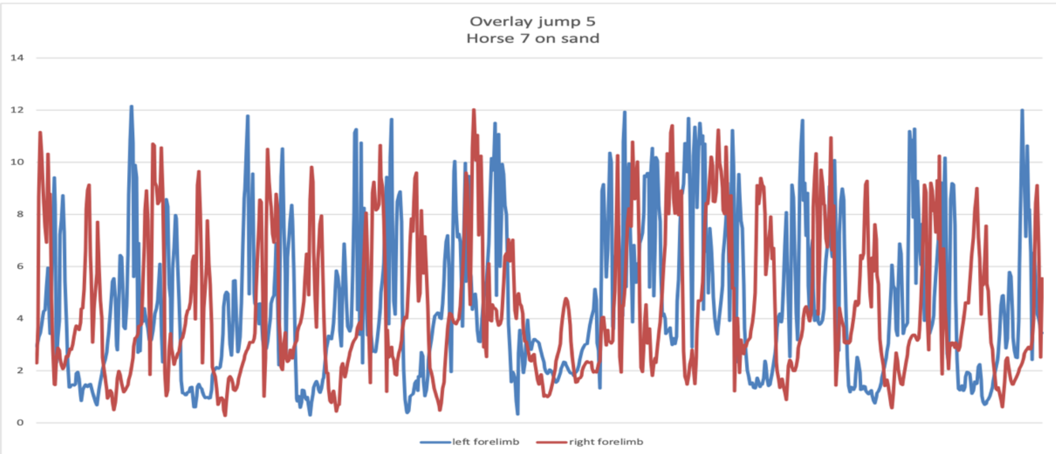
left forelimb
right forelimb


Overlay jump 5
Horse 7 on sand
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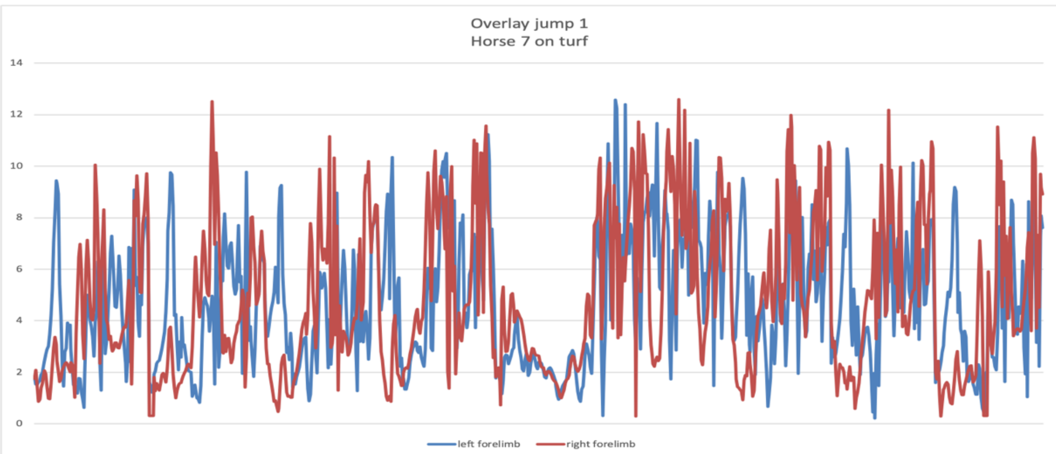
Overlay jump 1
Horse 7 on turf
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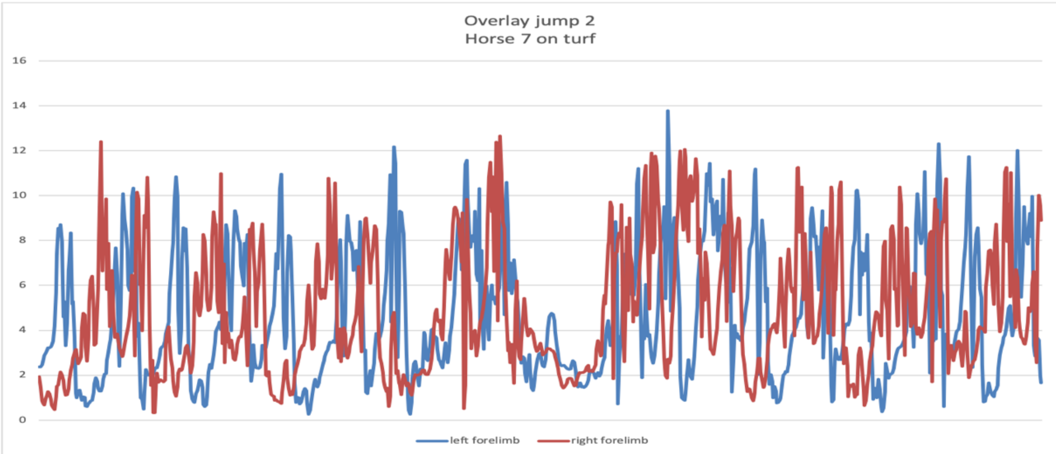
right forelimb


Overlay jump 2
Horse 7 on turf
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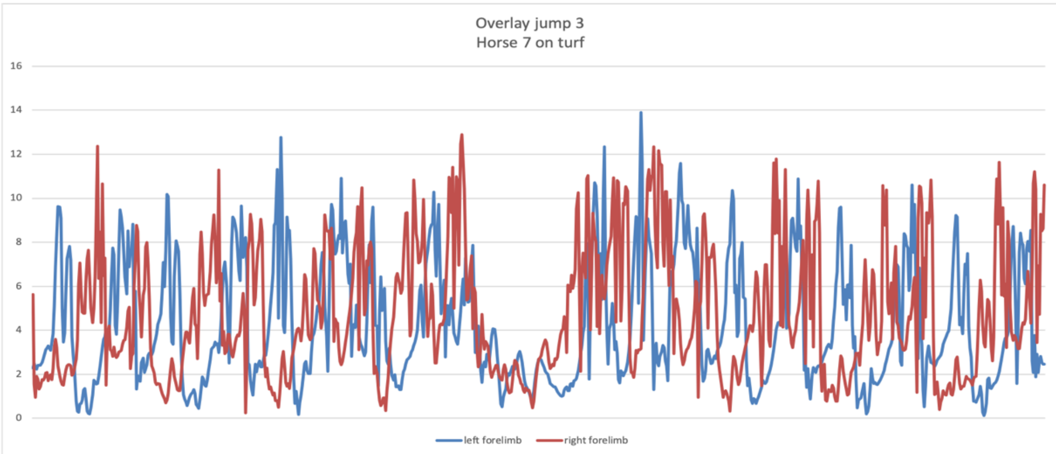
right forelimb


Overlay jump 3
Horse 7 on turf
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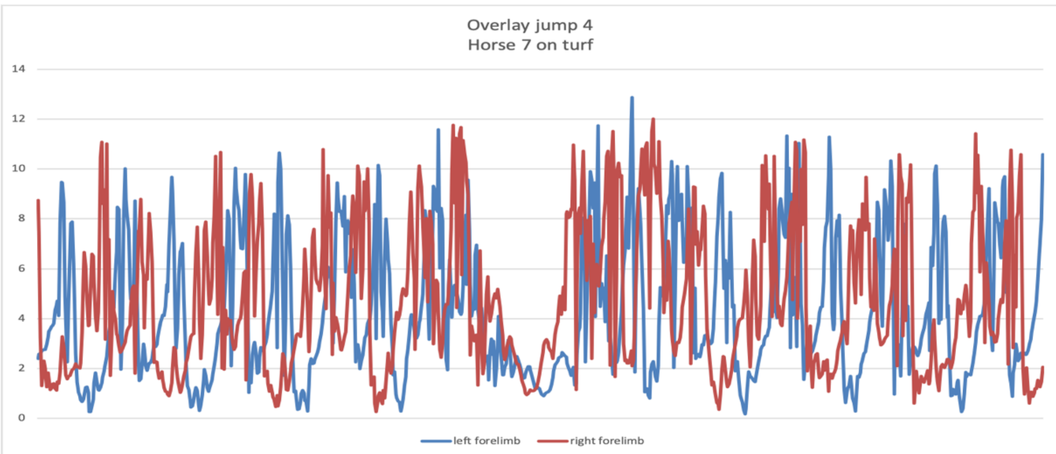
Overlay jump 4
Horse 7 on turf
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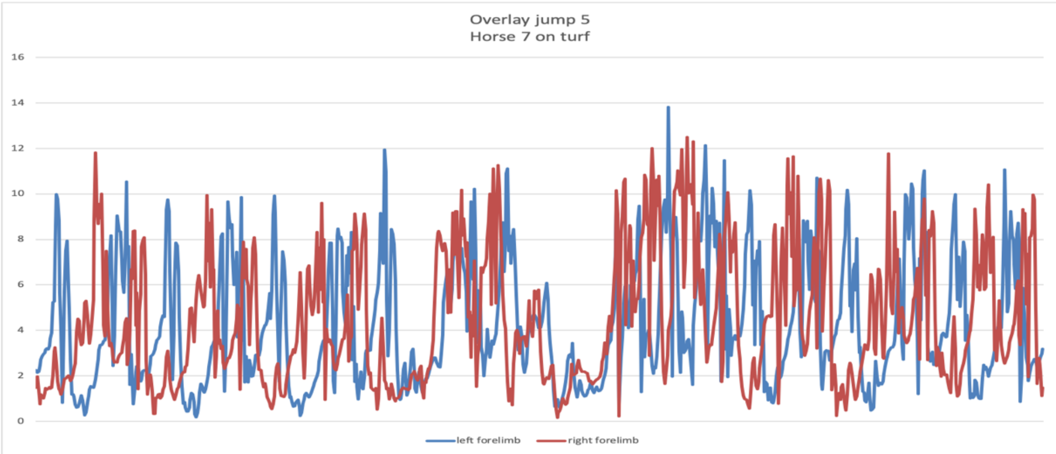
Overlay jump 5
Horse 7 on turf
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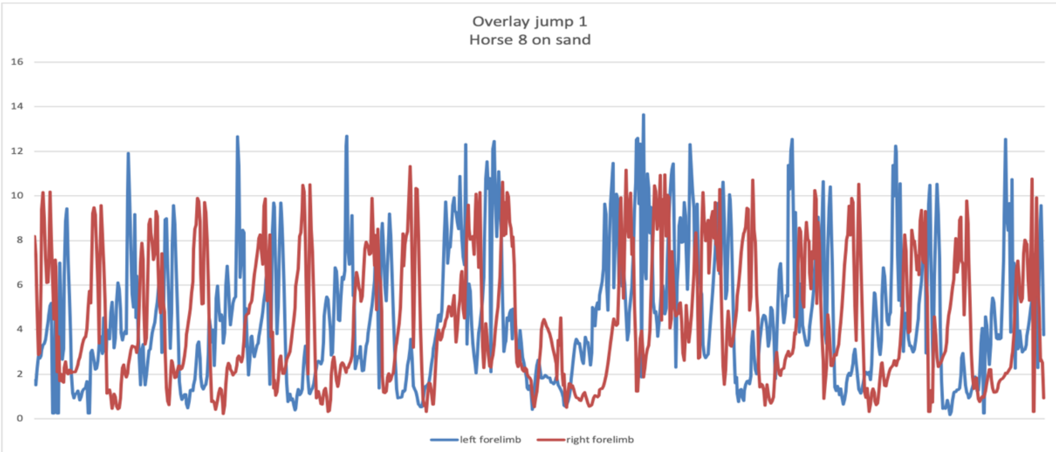
Overlay jump 1
Horse 8 on sand
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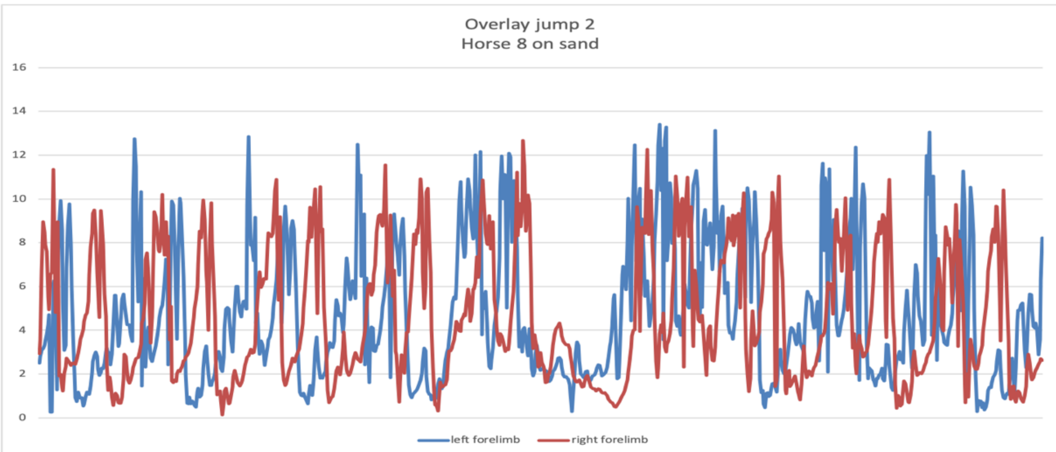
Overlay jump 2
Horse 8 on sand
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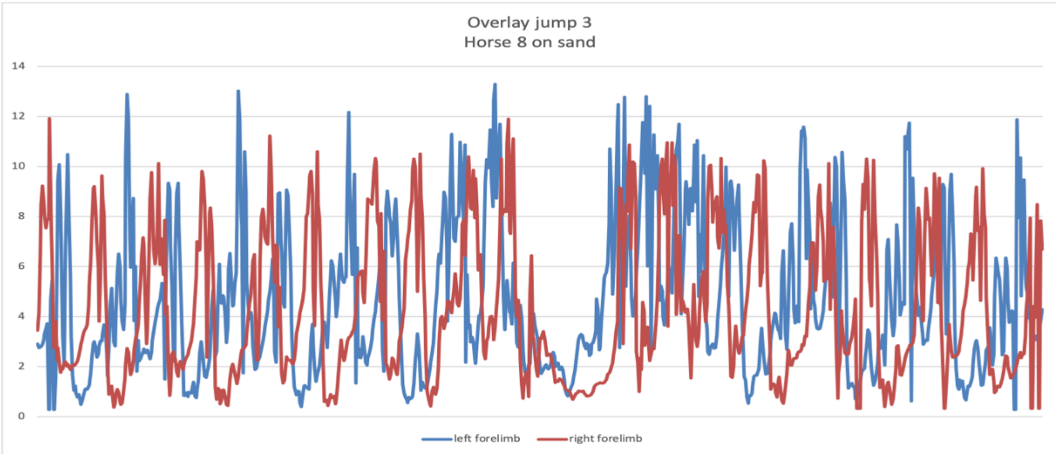
Overlay jump 3
Horse 8 on sand
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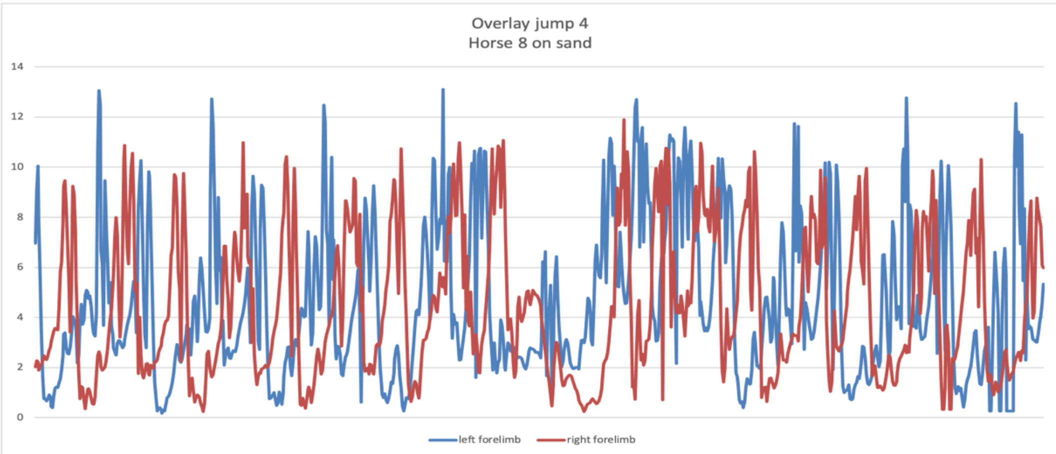
Overlay jump 4
Horse 8 on sand
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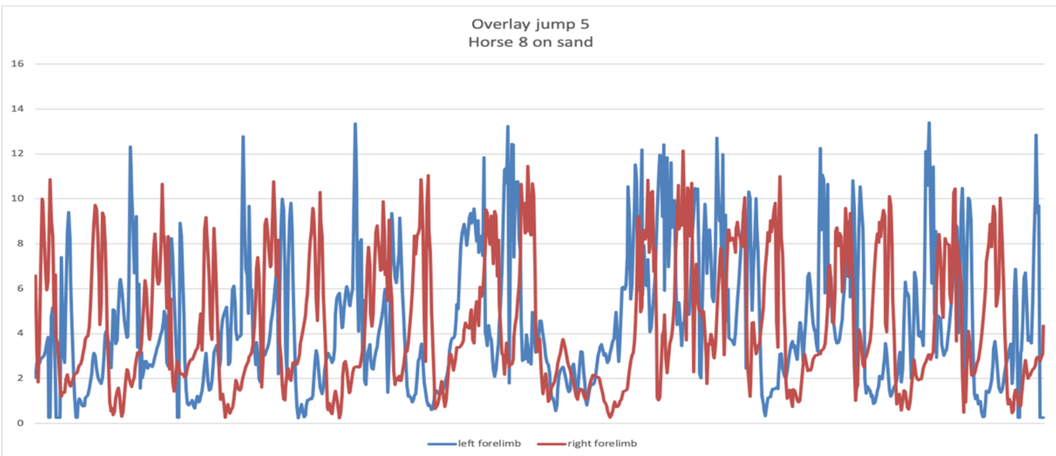
Overlay jump 5
Horse 8 on sand
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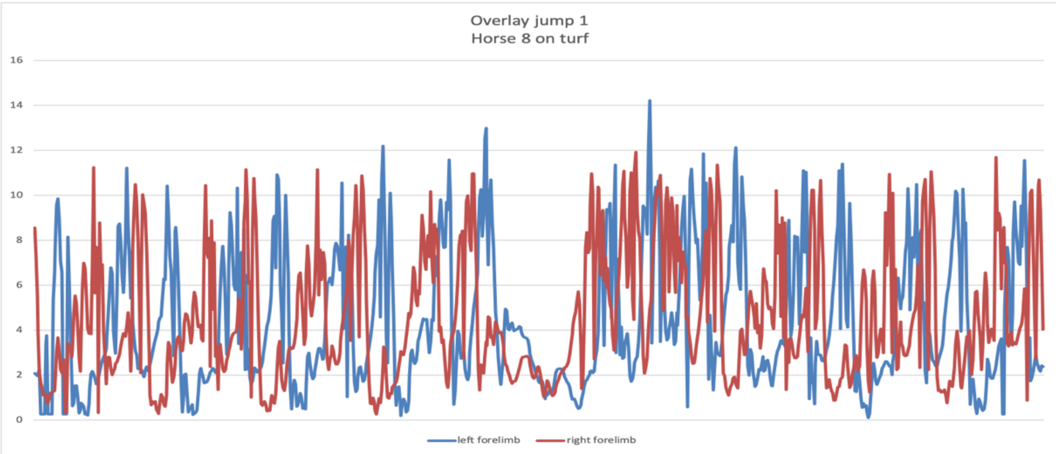
Overlay jump 1
Horse 8 on turf
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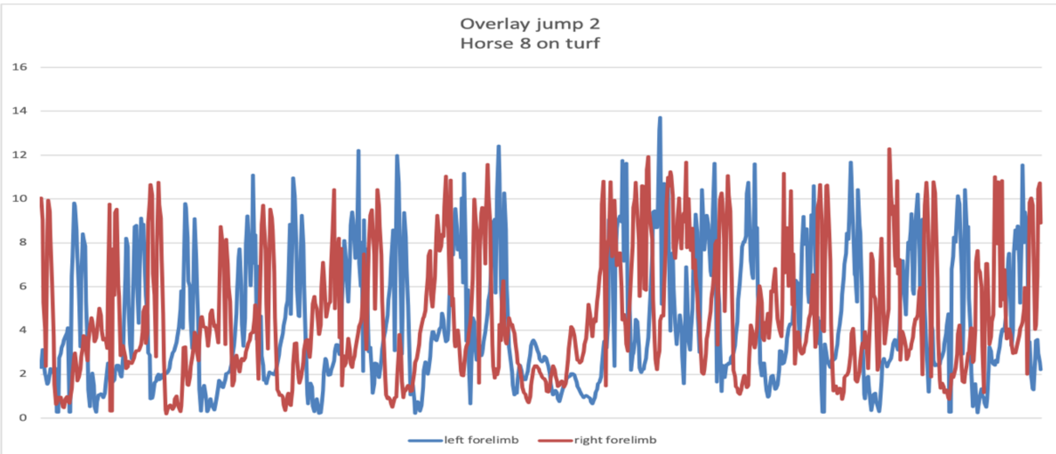
Overlay jump 2
Horse 8 on turf
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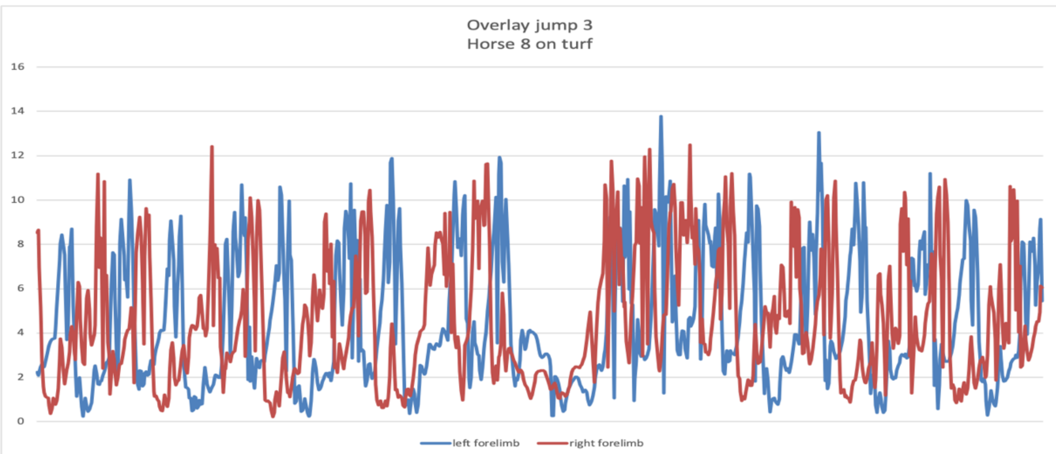
Overlay jump 3
Horse 8 on turf
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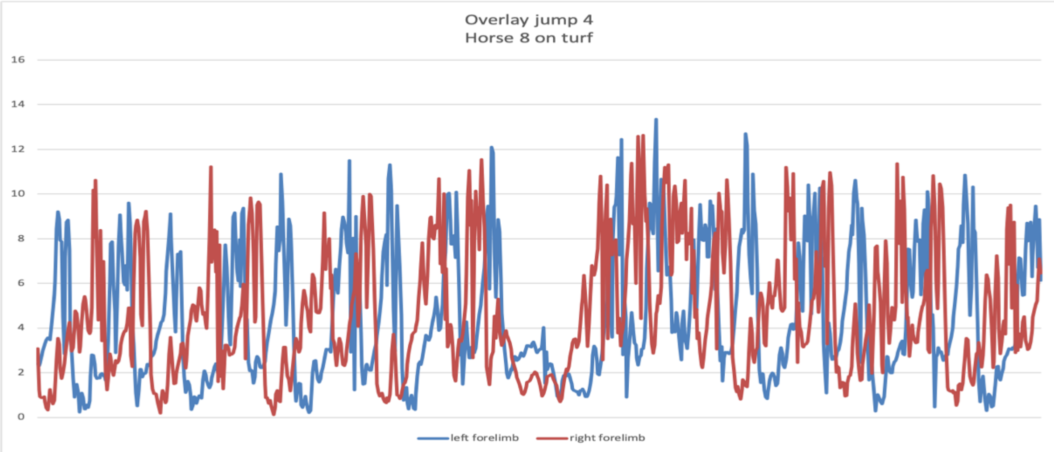
Overlay jump 4
Horse 8 on turf
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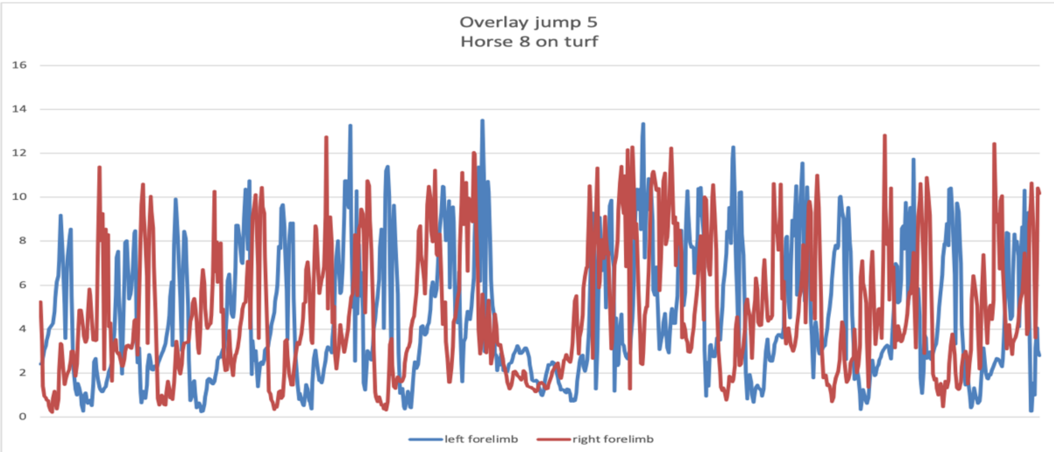
Overlay jump 5
Horse 8 on turf
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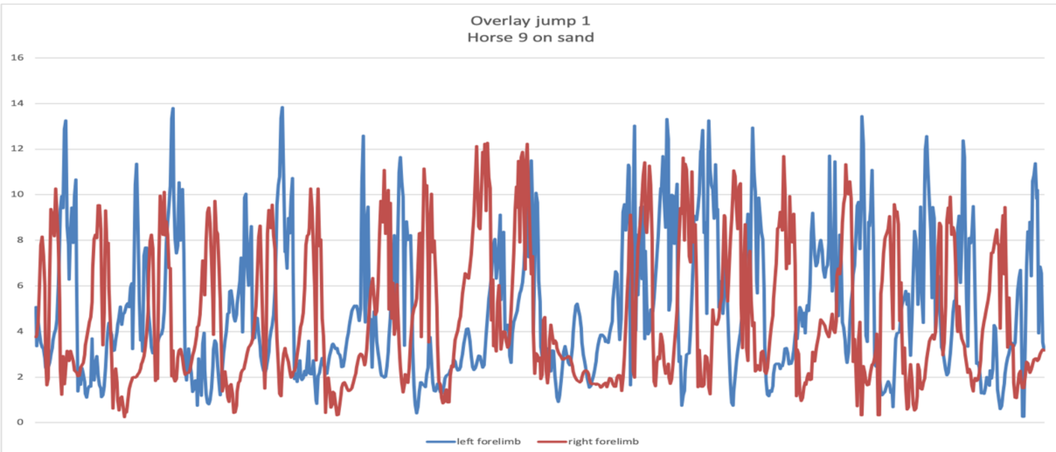
Overlay jump 1
Horse 9 on sand
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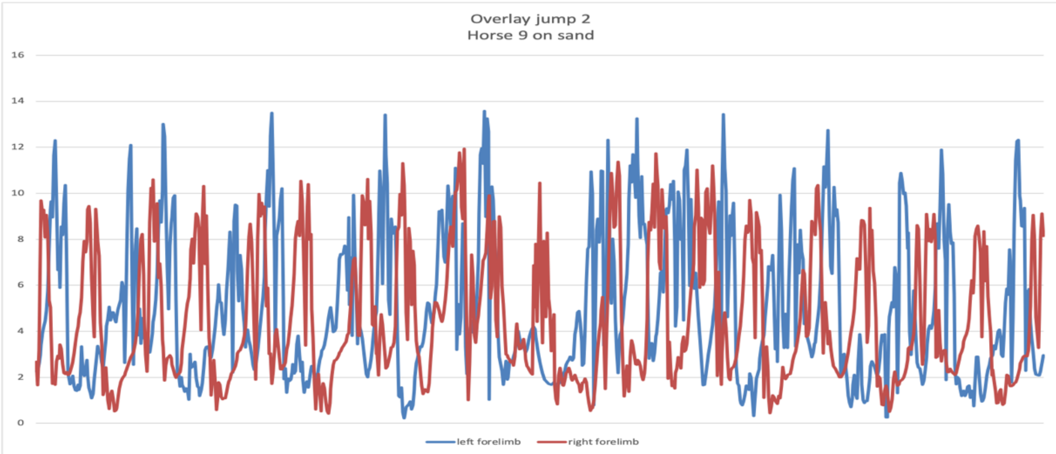
Overlay jump 2
Horse 9 on sand
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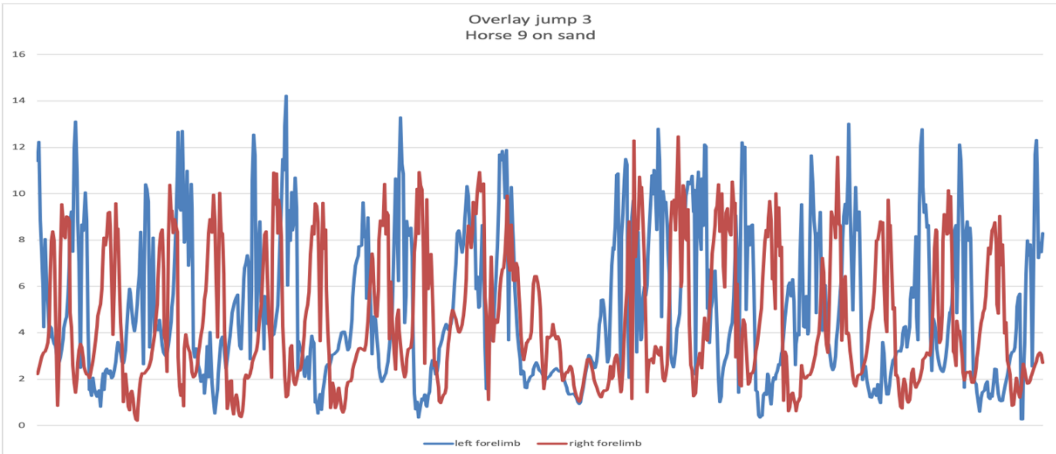
Overlay jump 3
Horse 9 on sand
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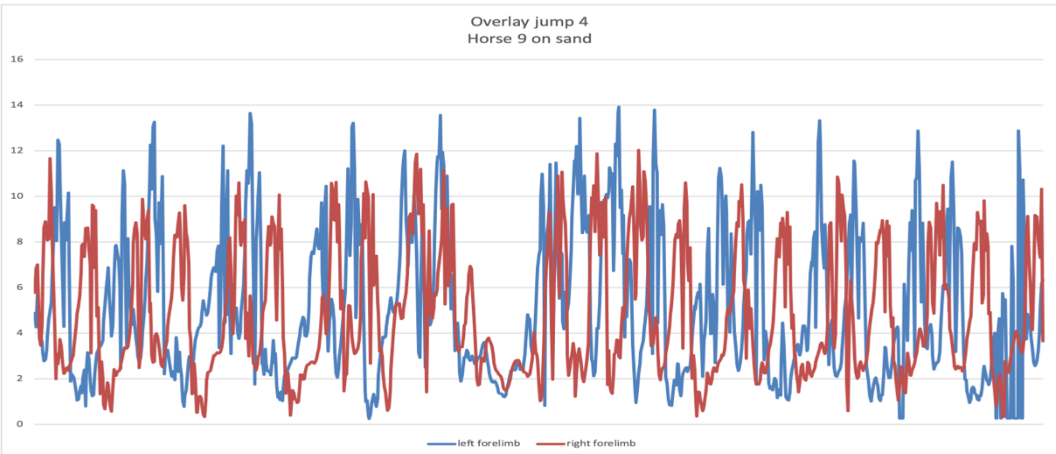
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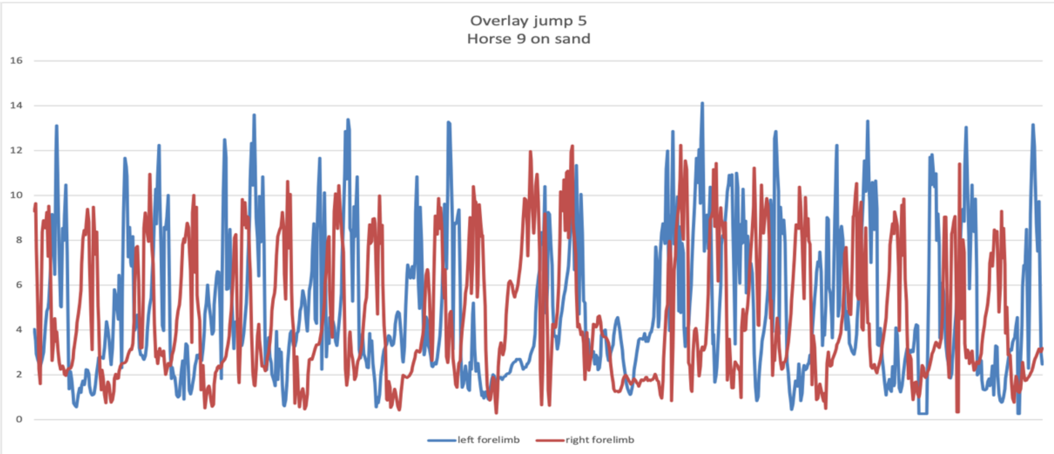
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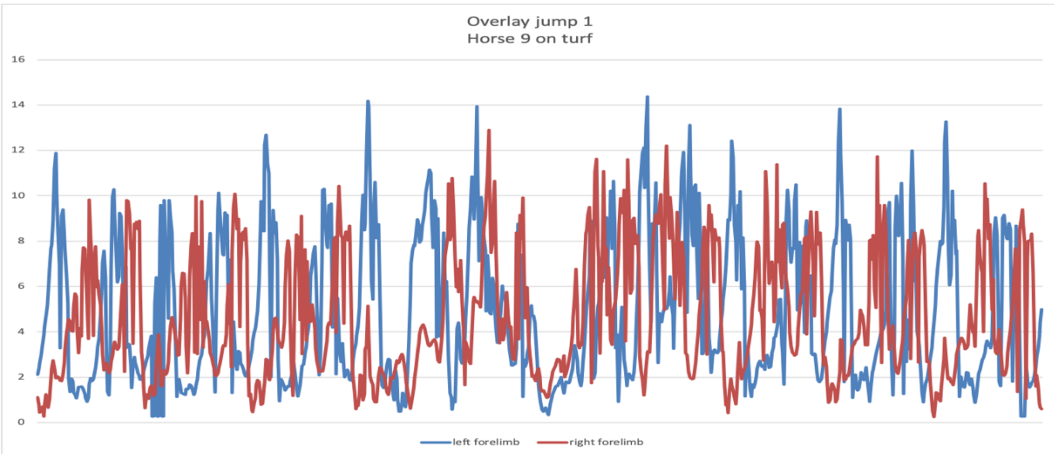
Overlay jump 1
Horse 9 on turf
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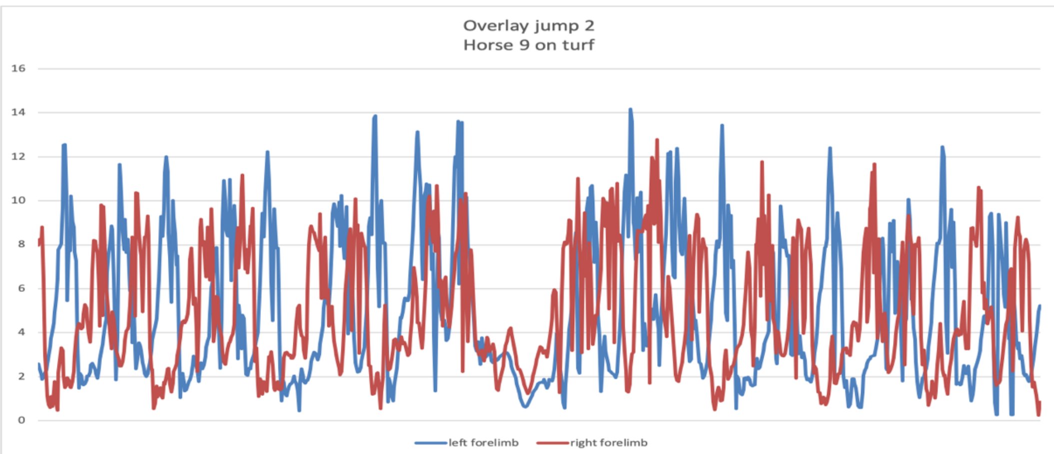
Overlay jump 2
Horse 9 on turf
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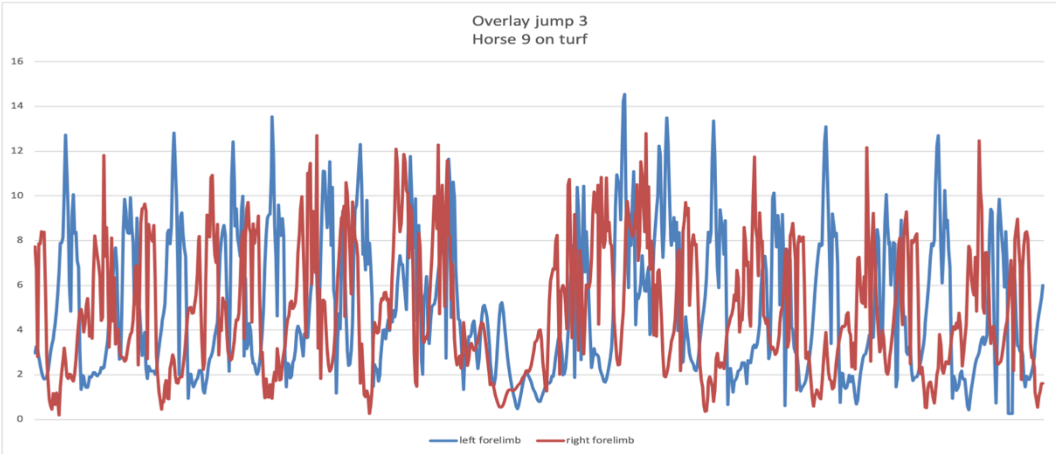
Overlay jump 3
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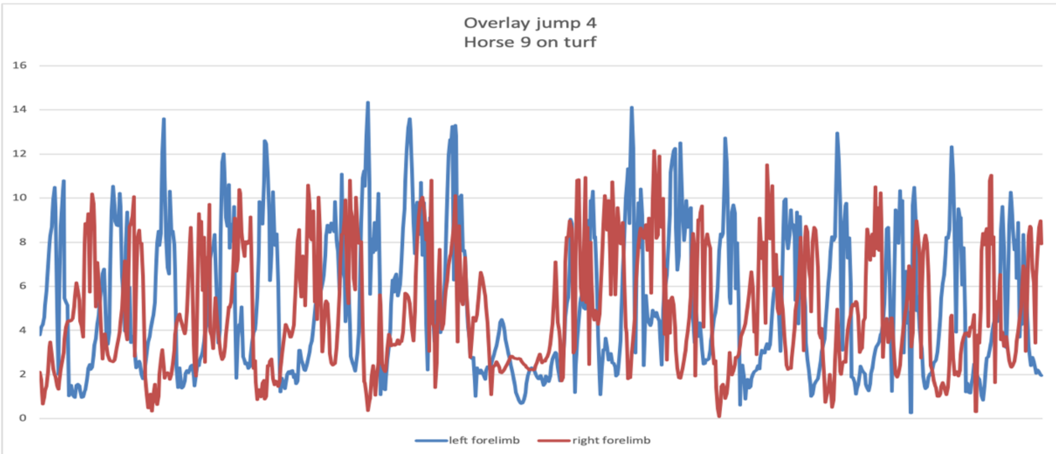
Overlay jump 4
Horse 9 on turf
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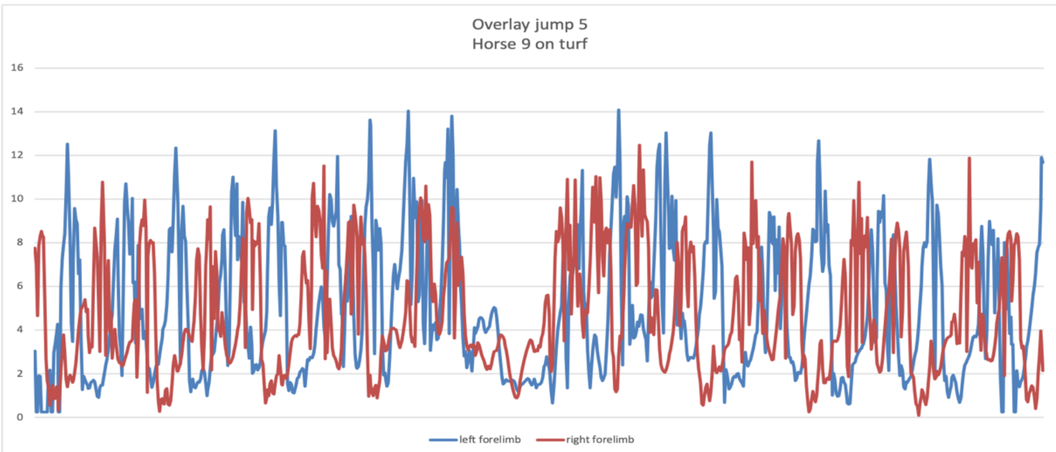
Overlay jump 5
Horse 9 on turf
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