Preliminary Computational Analysis of Gait Data Collected from Xylazine-Induced Ataxic Horses

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Introduction:

There is a need for reliable and more objective measures for assessment of horses with neurological disease. To score ataxia (incoordination), veterinarians use a grading scale from 0 (sound) to 5 (recumbent). However, this scale lacks discrimination and there is little agreement between clinicians [1], which is similar to what has been found for assessment of lameness in horses [2, 3]. Investigating the use of wearable devices for gait pattern recognition is a start to improving gait evaluation of horses [4]. Inertial measurement unit (IMU) devices can be used to objectively examine gait patterns; however, currently the data must be analyzed manually, which is time consuming. Here, our objective was to use MATLAB (Mathworks, Natick, MA) in automated data analysis to look at stride frequency and stride time.

Hypothesis: When horses walk, there is a statistical difference between the stride time and frequency before and after sedation.

Materials & Methods:

- Sound horses of multiple breeds (n=14), aged 5-15, were sedated following collection of control data to induce ataxia
  - Data were collected over two weeks, resulting in two time-points of Control data collection (prior to high dose (HD, 0.7 mg/kg IV) and low dose (LD, 0.2 mg/kg IV) xylazine)
- 9-axis IMUs (Gulf Coast Data Concepts) were attached to each horse using tape or Velcro to the lateral distal cannon bone ("ankle") – see Figure 1
  - Recorded linear acceleration and angular velocity
- Horses were walked across a flat surface 30m long, head neutral

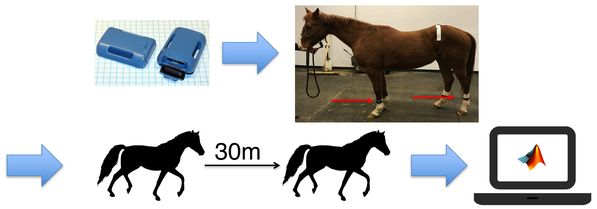


Figure 1. Data collection from IMUs to MATLAB.

- Data from n=6 horses were analyzed, stride frequency and stride time were calculated and compared
- Horse data chosen based on data completeness

Results:

- Developed over 5 versions of custom scripts to reach current scripts used for data analysis
  - 90+ hours of work
- Scripts are useable by all with extensive commenting (Figure 2) to walk through process
- Time to run MATLAB analysis: <20 minutes per file

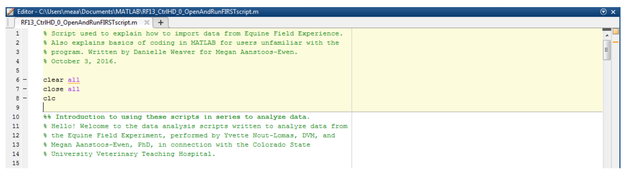


Figure 2. Example of commenting in the MATLAB scripts to show users how to run scripts and in what order to use them.

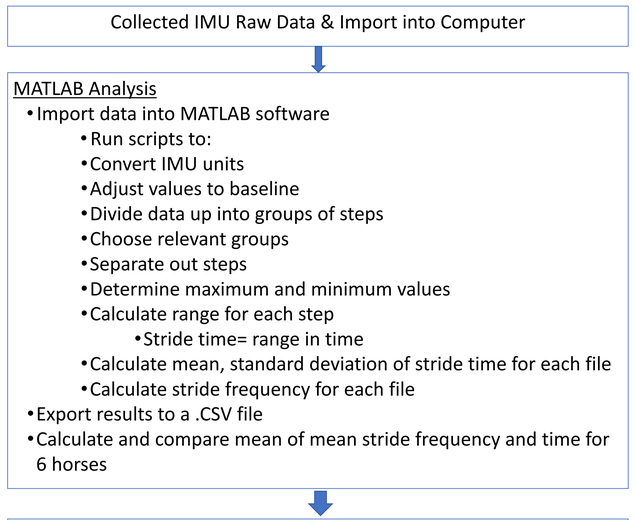


Figure 3. Flow chart of the data analysis performed on the IMU data.

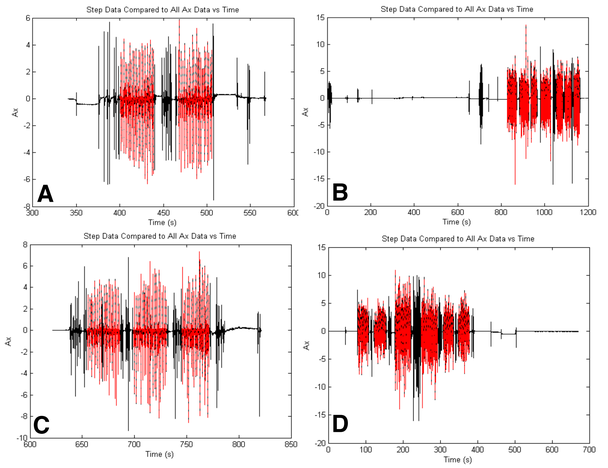


Figure 4A-D. Output graphs from the MATLAB data analysis of the left hind leg blindfold (A & C) and walk (B & D) acceleration data from Control HD (A,B) and LD (C,D) conditions measured in Horse 1. The black data indicates all the raw Ax data contained in the IMU data file. The red data indicates the Ax data analyzed by the MATLAB script.

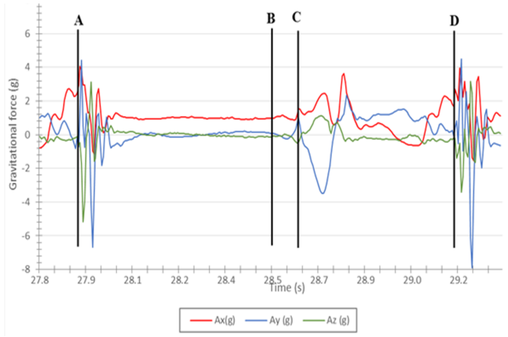
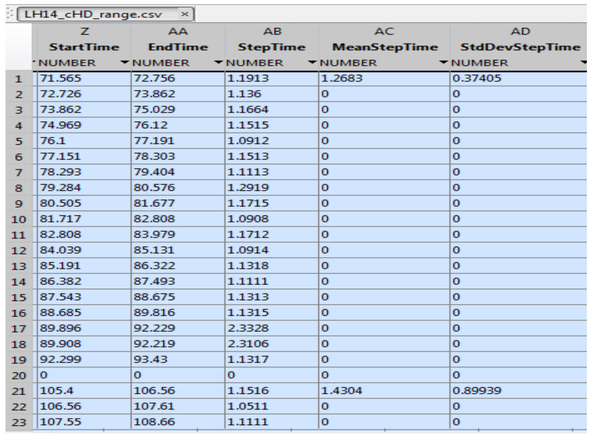


Figure 5. Example of a single step. Ax represents acceleration in the up/down direction, Ay in the nose/tail direction, and Az in the medial/lateral direction. A-D represents one complete step, or stride.



LH14_cHD_range.csv

	Z StartTime	AA EndTime	AB StepTime	AC MeanStepTime	AD StdDevStepTime
	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
1	71.565	72.756	1.1913	1.2683	0.37405
2	72.726	73.862	1.136	0	0
3	73.862	75.029	1.1664	0	0
4	74.969	76.12	1.1515	0	0
5	76.1	77.191	1.0912	0	0
6	77.151	78.303	1.1513	0	0
7	78.293	79.404	1.1113	0	0
8	79.284	80.576	1.2919	0	0
9	80.505	81.677	1.1715	0	0
10	81.717	82.808	1.0908	0	0
11	82.808	83.979	1.1712	0	0
12	84.039	85.131	1.0914	0	0
13	85.191	86.322	1.1318	0	0
14	86.382	87.493	1.1111	0	0
15	87.543	88.675	1.1313	0	0
16	88.685	89.816	1.1315	0	0
17	89.896	92.229	2.3328	0	0
18	89.908	92.219	2.3106	0	0
19	92.299	93.43	1.1317	0	0
20	0	0	0	0	0
21	105.4	106.56	1.1516	1.4304	0.89939
22	106.56	107.61	1.0511	0	0
23	107.55	108.66	1.1111	0	0

Figure 6. Picture of a characteristic output CSV file for stride time. The "StepTime" column for each data set was averaged to get an average step time for that horse, leg, and sedation condition. Then, files from multiple horses for the same leg and sedation condition are averaged to get mean-of-mean values, where n = the number of horses.

Table 1. Comparison of stride time and frequency between our experiment and a "gold standard" treadmill experiment [4].

Gait Factor	Data Source	Control LD	Control HD	Low Dose	High Dose
Stride Time (s)	Nout-Lomas 2016 [4]	~1.2		~1.3	~1.4
	Std Dev	0.05		0.04	0.02
	This Project (LF, LH)	1.76, 2.17	1.43, 1.35	1.47, 1.29	1.63, 1.58
	Std Dev	0.66, 0.97	0.13, 0.97	0.23, 0.052	0.17, 0.11
Stride Frequency (steps/s)	Nout-Lomas 2016 [4]	~0.92		~0.83	~0.75
	Std Dev	0.08		0.05	0.03
	This Project (LF, LH)	0.61, 0.55	0.70, 0.75	0.69, 0.77	0.62, 0.63
	Std Dev	0.15, 0.24	0.07, 0.05	0.09, 0.03	0.06, 0.05

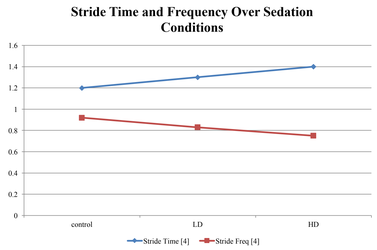


Figure 7. Graphical representation of what we expect to see for stride time (blue) and stride frequency (red) [4].

Discussion:

- From similar experiment presented in the previous Nout-Lomas 2016 paper [4]:
  - Expected stride time and frequency patterns for sedation levels determined

Stride Time	Control < LD < HD
Stride Frequency	Control > LD > HD

  - Done using "gold standard" equipment (video cameras, treadmill) and conditions
- Our data suggests that this automated method of analysis is not accurate for stride time
  - Similar but non-significant patterns for Control HD, LD, and HD data
  - Presence of outliers in control data may be skewing results

Conclusions:

- Automated method needs revision
- Better identify outliers
- Reassessment of start and end points of strides

Future Directions:

- Elimination of outliers in control data
- Look at other gait factors to quantify lameness – ex. changes in medial / lateral movements

References:

[1] Olsen E, Dunkel B, Barker W, et al. Rater agreement on gait assessment during neurologic examination of horses. JVIM 2014;28(2):630-638.

[2] Hewetson M, Christley R, Hunt I, Voute L. Investigations of the reliability of observational gait analysis for the assessment of lameness in horses. Vet Rec 2006;158(25).

[3] Keegan K, Dent E, Wilson D, et al. Repeatability of subjective evaluation of lameness in horses. Equine Vet J 2010;42(2):92-97.

[4] Nout-Lomas, Y.S.; Page, K.M.; Kang, H.G.; Aanstoos, M.E.; Greene, H.M. (2016) Objective Assessment of Gait in Xylazine-Induced Ataxic Horse. EVJ Jun 14. doi: 10.1111/evj.12602.

Acknowledgments:

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