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Limb phasing Icelandic horses

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Abstract

Twenty Icelandic horses were studied using the ETB limb phasing system measuring the speed, stride length, stride duration and symmetry of fore-, hind- and diagonal limbs of different gaits. The ETB system measures the time-within the stride relationship between the four limbs, calculated through a continuous cross correlation between the cannon bone angle of the left hind (LH) and the other limbs respectively. Each horse showed the gaits it was considered able to perform of walk, trot, canter, tölt and pace. Representative strides of each gait were selected for analysis.

The results showed that walk, tölt and trot were similar with respect to symmetry of front and hindlimbs. Albeit that only few measurements were done in pace, these clearly differed from the other gaits defined as symmetric, as being less symmetric. The mean values for left and right canter differed in speed and limb phasing pattern. In further studies it would be of interest to study both more horses and more five-gaited horses in order to determine whether Icelandic horses overall show handedness more in pace compared to other gaits (i.e. are more asymmetric) and to study the differences/similarities between left and right canter.

Contents

1 Introduction

Icelandic horses become more and more popular. The breed is well known for its ability to perform up to five gaits. Except of walk, trot and canter the Icelandic horse also moves in tölt and pace. The gaits are important in training and when competing with Icelandic horses. Today the quality of the gaits at competitions and breeding shows are judged by the human eye.

When judging the gaits a clear beat is important. For example, the trot should be 2-beated and the canter 3-beated. This means that focus is on the number of time-separated hoof events per stride in the gait, which is often registered by human perception, i.e. vision or hearing. The movement pattern varies between horses and it is sometimes difficult to see if the beat is clear on a fast moving horse. At high speed pace it is often difficult to see whether the pace has a clear 2-beat and whether there is a suspension phase or not.

A more accurate evaluation at breeding shows and competitions would help the breed to achieve more accurate results and thereby faster improvement. A system measuring the movements objectively could be a valuable complement to the human eye when judging Icelandic horses.

1.1 ETB Pegasus Limb Phasing

ETB-Pegasus Limp Phasing (ETB-Pegasus, 2011) is a system measuring movements of the horse. The system consists of four synchronized sensor monitors fitted to brushing boots mounted on each cannon bone of the horse and a GPS (Global Positioning Sensor). In ridden horses the GPS sensor is fitted on the rider.

The sensors measure the angles of the cannon bones and the limb phasing is not equivalent to the hoof beat of the gait. For each trial the system measures the number of strides and the distance traveled. Stride length and speed are measured for each stride. Within each gait the limb phasing, the time-within the stride relationship between the four limbs, is calculated through a continuous cross correlation

between the cannon bone angle of the left hind (LH) and the other limbs respectively. A position chart is made after each ride, i.e. from the GPS the location of the ride is mapped.

The system usually refers to the left hindlimb (LH), i.e. this is set to 0%. If the gait is symmetric the right hindlimb (RH) is then assumed to be at 50%, i.e. to come exactly after half of the stride cycle.

For example, in a study using the ETB Limb Phasing system, horses were walked on a straight line and the mean percentage of limb phasing in the walk was for the left front (LF) 32%, the right hind (RH) 49%, the right front (RF) 81%, all referenced to the LH. Since the front- and hindlimbs have different movement patterns, a clean 4-beat walk will not be shown as 0%, 25%, 50% and 75% in the limb phasing system. (ETB-Pegasus. 2011)

1.2 Gait analysis

A gait can be defined as a coordinated rhythmic pattern of motion which results in movement.

The characteristics of gaits can be defined in several ways (Barrey, E. 2008)

- Symmetric gaits: walk, tölt, trot and pace
- Asymmetric gaits: canter and gallop
- Running gaits: trot, canter, gallop, pace and tölt
- Walking gaits: walk.

Measurements of horse locomotion can be done with kinetic and kinematic analysis. Kinematic analysis studies the geometry of the movements without considering the forces of the movements. Common is to use videographic or optoelectronic equipment to analyze movements. Kinetic analysis measures the forces of movements. Kinematic studies often demand a lot of equipment and take more time to analyze. (Barrey, E. 2008; Clayton & Schamhardt. 2001)

Each gait has a continuous variation, e.g. with speed, and the difference between gaits can sometimes be subtle. Variations within gaits are for example due to beat, speed and collection. (Barrey, E. 2008, Nicodemus et al. 2003)

Riding and training horses affects the horse. The results can have both strengthening and weakening affects on the musculoskeletal system. (Burn et al. 1997) When training horses, one goal is to train the horse for longevity and health. It is stated that horses must be trained to be symmetrical and equally strong on both

sides, to be able to carry the rider equally much on both sides. This can be identified as symmetry.

1.2.1 Common words in gait classification:

One stride is one limb cycle of motion. A gait develops when similar strides are repeated. For each limb, one stride consists of a stance phase when the limb is on the ground and a swing phase when the limb is not on the ground. Trot, canter, gallop and pace also consist of a suspension phase when no limb is in contact with the ground. (Barrey, E. 2008)

The stride duration can be defined as the time of one stance phase and one swing phase of one limb. The stride duration decreases with speed, as the stride frequency increases. (Robilliard et al. 2007)

A diagonal stance phase is where a hindlimb and the diagonal forelimb are at the ground at the same time. *A lateral stance phase* is where a hindlimb and the same side's (ipsilateral) forelimb are at the ground at the same time. (Barrey, E. 2008)

The stride frequency is the number of strides per time unit. The stride frequency is often expressed in hertz (Hz) or in strides/s. (Barrey, E. 1999)

The overtrack distance is the distance between one hindlimb imprint and its ipsilateral forelimb imprint. If the hindlimb imprint reaches over the forelimb *overtrack* distance overtrack is positive, while if the hindlimb imprint does not reach the same position as the imprint of the ipsilateral forelimb it is negative. (Barrey, E. 2008)

The beat of a gait is the relationship between footfalls during a stride. (Barrey, E. 2008)

Advanced placement occurs when fore- and hindlimbs hit the ground non-synchronized in a lateral or diagonal gait (lateral advanced placement and diagonal advanced placement). When the hindlimb hits the ground first it is called positive advanced placement and negative advanced placement is when the forelimb hits the ground first. (Clayton, H.M. 1997)

1.3 Gaits of the Icelandic horse

Whether a gait should be defined as a walking or a running gait may be defined as whether there is a suspension phase or not. (Barrey, E. 2008) Starke et. al. 2009 found that tölt is more similar to walking regarding the PR (the phase relationship between kinetic and potential energies) and air time (the time when no limb is in contact with the ground). With respect to having a shorter duty factor (the relative

value between stance phase and stride time) and higher dimensionless speed (speed in correlation to gravity and withers height) tölt is more similar to running.

Tölt has been described as a four beat gait with the footfall sequence/order LH, LF, RH, RF. The time between the footfalls should be even between all limbs. One or two limbs will be in stance phase at the same time and therefore no suspension phase occurs. (FEIF. 2011a)

Nicodemus and Clayton (2003) demonstrated that some horses have three limbs in stance phase at the same time in slow tölt (e.g. tripedal support). The tölt strides studied were from horses that the breeding association considered as a representative sample of horses competing at national level (mean stride duration 574 ms). However, Robilliard et al. 2006 did simply not identify strides with tripedal support as tölt, since such strides did not follow the gait definition of FEIF and they were omitted (FEIF. 2011a). Instead such strides were defined as a walk-tölt hybrid but basically left unclassified. Zips et al. 2001 did not detect tripedal support but found that Icelandic horses had a suspension phase in tölt of higher speed, i.e. when reaching 4.4 m/s. Only one of 23 horses did not show a suspension phase in fast tölt. The results of Nicodemus & Clayton, 2003 and Zips et al. 2001 indicate that the definition of tölt should be reviewed and tripedal support and/or suspension phase characteristics should be included where relevant.

A challenge when characterizing gaits is that there is no distinct difference between gaits and one gait merges to another in a continuum. (Nicodemus, M.C. & Clayton, H.M. 2003)

Zips et al. 2001 showed that the beat varies a lot in tölt, both within horses and between horses. The beat varies from tölt with longer diagonal moments (trot beat tölt) to longer lateral moments (pace beat tölt).

In a study of Robilliard, J (2006) gaits of Icelandic horses were studied and 2% of the tölt-strides were incorrectly classified as pace and 19% of the pace strides were incorrectly classified as tölt. This is evidence of pace being slightly four beat.

1.4 Breeding goals relative to gaits

The breeding goals of FEIF, the International Federation of Icelandic Horse Associations relative to gait characteristics are as follows (FEIF 2011b):

Tölt: Even 4-beat rhythm with long strides in front and behind, lots of lift and action of the front legs, movements extremely flexible and supple, excellent high speed.

Slow tölt: Even 4-beat tölt with long strides in front and behind, elegant action and movement of the front legs, movements extremely flexible and supple.

Trot: Confident 2-beat trot, movements high and supple, long strides and suspension. Excellent speed.

Pace: Confident, impressive pace, good 2-beat lateral gait with good suspension and excellent speed.

Canter & gallop: Good beat. An attractive gallop: the horse is well off the forehand yet stretches out in nice round, powerful movements with good suspension. Excellent speed.

Slow canter: Effortless, yet impressive, supple, 3-beat canter with good suspension; uphill, the horse is well off the forehand.

Walk: The horse is impressive and walks forward enthusiastically, with an even beat and a supple body. The head is carried at medium height and the horse moves with long, energetic strides, tracking up well.

Additionally for tölt is stated that: " Required is an even 4-beat gait without suspension, 1 or 2 feet on the ground at any single moment. " (FEIF 2011a).

1.5 Aims and hypothesis

This study aims to study the symmetry in different gaits of the Icelandic horse and by this to evaluate whether the ETB- limb phasing system could be used in breeding shows and/or competitions as an objective tool for the judges.

Hypotheses are that there will be significant differences between gaits for the parameters derived from the ETB limb phasing system and therefore that the system could be a useful tool for Icelandic horse breeding shows and/or competitions.

2 Material and methods

In this study, 20 Icelandic horses were measured with the Pegasus limb phasing system. The measurements were done August-November 2010 in Sweden.

2.1 The horses

Both four- and five gaiters were measured. The horses were of different age, sex and education level. There were:

- 6 riding school horses
- 6 light competition/leisure horses
- 5 young horses, seemingly talented as judged by their owners
- 3 elite horses attending international competitions

All horses were ridden by 6 experienced riders. The number of horses shown by each rider was 7, 4, 4, 3, 1 and 1. The horses were stabled at four different locations.

2.2 The measurements

Brushing boots with sensors were mounted on each limb of the horse. A GPS was fastened on the rider's helmet.

Before the measurements started the horses were led with the equipment mounted to make the horses used to it. The horses underwent ridden trials equal/similar to those at a breeding show. Every horse was ridden on a straight track showing four or five gaits, depending on if the horse was able to show pace or not. The riders decided in which order they wanted to show the gaits. If possible both slow and extended versions of tölt and canter/ gallop were shown.

2.3 The analysis

The data of all strides were imported and managed in Excel (MS Excel, Microsoft Corporation, Redmond, WA 98052-6399, USA). Strides from each gait were visually selected by the author during the test and later from the data in excel. Mean limb phasing data from all strides of each of the specific gaits were used. Means and standard deviations from all mean data were calculated.

Where there seemed to be beat variations, specifically tölt with longer ipsilateral stance phases (pace beat) or with longer diagonal stance phases (trot beat) the strides were named diagonal tölt and pacy tölt, and separately tabulated. Pace was the most complicated gait to identify, since the hindlimb touches the ground before the ipsilateral forelimb, also the limb phasing appears similar to tölt. Pace was also considered most difficult to identify by Robilliard et al, 2007.

Differences in symmetry between forelimbs, hindlimbs and diagonal limbs were estimated/quantified. Symmetry was calculated by the author using limb phasing data. RH subtracted from LH is supposed to be 0.5 in symmetric gaits. The same were done on the forelimbs. Diagonal symmetry was calculated by subtracting the diagonal limb phasing values from each other.

Mixed model analysis (PROC MIXED; SAS Institute Inc., Cary, NC, 27513, USA) was used to estimate fixed effects for gaits and for differences in symmetry between gaits, taking account of limbs-within-horse as random effects. The outcomes modeled were phase LF mean, phase RF mean, phase RH mean, hindlimb symmetry, forelimb symmetry, diagonal symmetry**.** Phase means, hindlimb symmetry and diagonal symmetry was only compared between symmetric gaits while forelimb symmetry were analyzed both only among the symmetric gaits and among all gaits. Probability values (limit 0.05) for differences between least square means were calculated to evaluate statistical differences between the gaits (option PDIFF in PROC MIXED).

3 Results

The difference between the forelimbs as well as for the hindlimbs in limb phasing is assumed to be 0.5 if the horse moves symmetrically. As seen in table 3, pace differs from the other gaits with respect to the differences between the phase means as being less symmetric than tölt and trot, the forelimb symmetry in pace is estimated to 0.46 whereas in tölt it is 0.5 and in trot 0.51.

Table 3 shows that there is a difference between left and right canter, both in mean speed and differences in phase mean between the limbs which indicates of different mean beat in right versus left canter.

In the comparisons of least square means LF and RF differs significantly from LH in all symmetric gaits ($p<0.0001$). In pace-trot and pace-tölt, the RH limb phasing differs significantly from LH (pace-trot $p=0.002$, pace-tölt $p=0.0007$). This is probably because of the asymmetry found in pace. The same is seen when comparing symmetry. Hindlimb symmetry was significantly different between pace-trot ($p= 0.002$) and pace-tölt ($p=0.0007$). No significant difference was found between tölt-trot ($p=0.58$). The forelimb symmetry (when comparing symmetric gaits) was significantly different between pace-trot ($p=0.03$) but not between pace-tölt ($p=0.08$), and tölt-trot ($p=0.26$).

Comparing canter to the symmetrical gaits there are significant differences in forelimb symmetry comparing to all other gaits ($p<0.001$). Because of the inherent asymmetry of canter, the forelimbs cannot move symmetrically.

Table 1. Number of horses showing each gait

Gait	Number of horses
walk	20
trot	20
tölt	20
pace	3
l canter	11
r canter	15
pace 4-beat	3
r canter 4-beat	2
tölt-pacy	3

Table 2. Comparison of symmetrical gaits All values shown are mean values.

	Strides	Speed	Stride duration	Stride length	LF phase	RF phase	LH phase	RH pha-se		Sy
	n	m/s (SD)	s (SD)	m (SD)	% (SD)	% (SD)	% (SD)	% (SD)	Front, %	Hin
Walk	63	1.45 (0.07)	1.02 (0.03)	1.46 (0.05)	0.33 (0.03)	0.82 (0.02)	0 (0.03)	0.5 (0.03)	0.49	0.5
Tölt	46	4.35 (0.29)	0.55 (0.01)	2.2 (0.12)	0.29 (0.03)	0.79 (0.02)	0 (0.03)	0.51 (0.02)	0.5	0.5
Trot	41	4.06 (0.31)	0.56 (0.02)	2.24 (0.16)	0.57 (0.03)	0.06 (0.06)	0 (0.03)	0.51 (0.03)	0.51	0.5
Pace	21	8.14 (0.24)	0.43 (0.01)	3.47 (0.07)	0.18 (0.01)	0.64 (0.08)	0 (0.00)	0.55 (0.06)	0.46	0.5

Table 3. Comparison between asymmetrical gaits. left and right canter. All values shown are mean values.

	Strides	Speed	Stride length,	Stride duration,	LF phase	RF phase
	n	m/s	m	s (SD)	% (SD)	% (SD)
Left canter	22	4.94	2.45	0.5 (0.05)	0.69 (0.06)	0.39 (0.04)
Right canter	32	6.77	3.03	0.45 (0.01)	0.35 (0.02)	0.63 (0.03)

Table 4. Variations of gaits, i.e. categorised sequences if the gait registrations that were not categorised into walk, trot, canter, tölt or pace

	StridesMean	SpeedMean, m/s, (SD)	StrideLengthmean, m (SD)	StrideDurMean, s (SD)	PhaseLFmean, % (SD)	PhaseRFmean, % (SD)	PhaseLhmean, % (SD)	PhaseRHmean, % (SD)
diagonal tölt	13	2.15 (-)	1.47 (-)	0.68 (-)	0.38 (-)	0.88 (-)	0 (-)	0.5 (-)
pacy tölt	62	3.81 (0.20)	2.02 (0.06)	0.54 (0.02)	0.22 (0.01)	0.73 (0.01)	0 (0.00)	0.52 (0.00)
4-beat pace	17	6.2 (0.35)	2.76 (0.23)	0.45 (0.02)	0.2 (0.08)	0.66 (0.05)	0 (0.00)	0.54 (0.04)
4-beat r canter	9	6.2 (0.07)	2.48 (0.01)	0.41 (0.01)	0.36 (0.02)	0.64 (0.04)	0 (0.00)	0.29 (0.01)
cross canter	7	6.36 (-)	2.63 (-)	0.41 (-)	0.07 (-)	0.35 (-)	0 (-)	0.8 (-)

cross canter	19	6.19 (-)	2.56 (-)	0.41 (-)	0.57 (-)	0.37 (-)	0 (-)	0.26 (-)

4 Discussion

4.1 Gait classification.

The general results show that there are significant differences between the gaits after the limb phasing analysis. In the analysis of LF- and RF phasing, relative to the reference LH, there were significant differences between the gaits. For some gaits, the phase means are different in relation to LH.

Differences for the limb phasing values of the forelimbs were found significant between tölt, pace and trot. Differences in limb phasing means comparing to RH were significant ($p<0.05$) between pace- trot and pace- tölt. There was no significant difference LH- RH between tölt and trot. Only three horses in the study showed acceptable pace and the mean value for RH was 0.6, not 0.5 as is assumed for symmetrical gaits and as was shown in tölt and trot. The oldest horse (16 years) actually showed a more symmetric pace with an RH value of 0.5 (data not shown).

In trot the mean value for the forelimb was 6% after the diagonal hindlimb, which is less than seen in warmblood riding horses (12%). (Roepstorff, L. 2011) This could be an indicator of that Icelandic horses might have their front hoof impact closer to the hindlimb (closer to a clean 2-beat) or that the front hoof is more likely to touch the ground even before the diagonal hindlimb (negative diagonal dissociation).

4.2 Symmetry

Training-related injuries among riding horses are perceived as common. One goal in horse training is to have the horse as symmetric as possible to be able to carry itself and the rider equally much on both sides. (Barrey, E. 2008). However, the handedness of the rider should also be taken into consideration. The balance of the rider and its' influence of the horse can have large effects on the horse's movement.

The limb phasing system is a measurement of how symmetrically the horse moves. Since LH normally starts at 0, it is assumed that RH is 0.5 if the horse moves symmetrically. Also the difference of the forelimbs is assumed to be 0.5 in symmetrical gaits.

According to the measurements in this study, pace differs from the other symmetrical gaits (table 2). Robilliard et al., 2007 also found that pace deviated most among symmetrical gaits and also had greater variation in forelimb-hindlimb ratios when comparing symmetrical gaits of Icelandic horses. Robilliard discussed that the handedness is more apparent in pace than in other gaits. The horse uses the powerful hindlimbs to push forward in flying pace. Also you want the horse to run as fast as possible. As the speed increases, horses prefer canter and often tries to start cantering. Since canter is an asymmetric gait this could influence a more asymmetric movement pattern in pace.

Overall one may suspect that Icelandic horses easier than other horses change their movement pattern and that there could be a relatively large within-gait beat variation. One reason the Icelandic horses may have more variable within-gait movement patterns because they can use up to five gaits.

4.2.1 Comparing symmetry

Hindlimb symmetry

When comparing hindlimb symmetry, the comparisons pace-trot and pace-tölt were significantly different ($p<0.05$), albeit tölt-trot was not. One reason could be that pace is least symmetric as seen from the symmetry values of pace (table 2).

Forelimb symmetry

The results show that there are significant differences in forelimb symmetry between pace-trot (comparing the symmetrical gaits), canter-pace, canter-tölt and canter-trot. The forelimb symmetry at pace and tölt ($p=0.07$ results not shown) did not differ significantly (but the hindlimb symmetry between the same gaits did).

Trot, tölt and pace are all symmetric gaits, but pace differs in the results and is least symmetric. In this study only three horses showed acceptable pace. Further studies on five-gaited horses with trained pace are needed.

The symmetry in canter is significant different from the other gaits. Canter is well known as an asymmetric gait and therefore the symmetry of canter should differ from the symmetric gaits in this aspect. .

4.3 Asymmetric gaits

Canter is an asymmetric gait, in one lead the left side moves differently than the right side (table 3). When comparing mean values of left and right canter, the speed difference is large, with means of 6.77 vs. 4.94 m/s and also the limb phasing is different between left and right lead. The diagonal which is supposed to move simultaneously (ex. LH and RF in left canter) differs in limb phasing from in left and right canter. In left canter, LH: 0.35, RF: 0.39. In right canter: RH: 0.32, LF: 0.35. In trot, the forelimb of each diagonal is 6% after the respective hindlimb. Assuming the same in canter would indicate that the diagonal in left canter is more similar to the same diagonal in trot, while in right canter the forelimb of the diagonal is 3% after the hindlimb, which could indicate a negative four beat, i.e. that the forelimb of the diagonal touches the ground before the hindlimb does, assuming that the trot is of clear 2-beat.

4.4 Benefits and limitations

The study consists of 20 horses, with diverse backgrounds which is good for the ability to extrapolate but may introduce substantial variation and imprecise results. It would be preferable to do a further study with more horses and especially more five-gaited horses since the pace differs from the other symmetrical gaits in this study.

By using the equipment on for example a competition the judges may be able to better judge whether the gaits are acceptable.

4.5 Future use

The aim of this study was to evaluate ETB limb phasing as an objective tool when judging gaits of Icelandic horses.

The Limb Phasing measures the movement of the cannon bone, phasing the limbs against a reference limb.

Since the horses in Icelandic breeding shows are only shown on a straight track, to use an indicator of horse symmetry could promote equally handed horses and encourage good training and thereby decrease the risk of injuries caused by inadequate training. In competitions the horses are not always shown on both hands which could lead to less encouragement to train symmetry in the horses. It is possible that more symmetrical horses could also improve the gaits and maybe especially pace where the horse is often sensitive to imbalance. Pegasus Limb Phasing is a handy system and the horse is allowed to perform in its normal environment which is a big advantage. The system could also be a useful tool when educating judges to train the human eye to see and look for symmetry in the horses.

When judging Icelandic horses, emphasis is put on the beat and sometimes it is difficult to see the beat of a moving horse. All horses move differently and the movement pattern of horses can vary a lot. Also it is difficult to see the beat when the speed is high.

With the limb phasing system it is not possible to directly refer to the beat, since the cannon bones of front- and hindlimbs move differently (and the system fastened to the cannon bones and not the hoofs). But because the system indirectly demonstrates the beat of the gait, this could still benefit the judging of Icelandic horses.

Lately it has been a discussion about judging pace. Since the horses move fast it is difficult to see if there is a clear 2-beat and a suspension phase, as it should be to be judged as flying pace. Horses with large movements often show a 4-beat gait with a suspension phase. Zips et al, 2001 measured extended tölt where many horses also had a suspension phase, sometimes the gaits come close to each other.

By doing further measurements it would be interesting to see how large the association between the limb phasing and the beat of the gait is. Improved symmetry in riding horses could give more sustainable horses with more stable and faster gaits.

References

Barrey, E. 1999. Methods, Applications and Limitations of Gait Analysis in Horses. The Veterinary Journal 157. 7-22.

Barrey, E. 2008. Biomechanics of locomotion in the athletic horse. In: Equine exercise physiology, The science of exercise in the athletic horse (eds. Hinchcliff, K.W., Geor, R.J., Kaneps, A.J.), 143-168. Elsevier Limited, Philadelphia, USA.

Burn, J.F., Wilson, A.M., Nason, G.P. Impact during equine locomotion: Techniques for measurement and analysis. Equine Vet J Suppl. 23. 9-12.

Clayton, H.M. 1997. Classification of collected trot, passage and piaffe based on temporal varuables. Equine vet. J. 1997: 29 (suppl. 23):54-57

Clayton, H.M., Schamhardt, H.C. 2001. Measurement techniques for gait analysis. In: Equine locomotion (eds. Back, W., Clayton, H.M.) 55-76. W.B. Saunders, London.

ETB- Pegasus. ETB-Pegasus Limb Phasing. [online] http://www.pegasus.uk.com/ (2011) Available from (http://www.pegasus.uk.com/wordpress/?page_id=80) [2011-02-15]

FEIF. International federation of Icelandic horse associations. [online] (2011a) Available from: (http://www.feiffengur.com/documents/SJGuidelines%202011.pdf) [2011-05-15]

FEIF. International federation of Icelandic horse associations. FEIF rules for Icelandic horse breeding. [online] (2011b) Available from: (http://www.feiffengur.com/documents/fizo11e.pdf) [2011-03-03]

Nicodemus, M.C., Clayton, H.M. 2003. Temporal variables of 4-beat, stepping gaits of gaited horses. Applied Animal Behaviour Science 80. 133-142.

Robilliard, J.J., Pfau, T., Wilson, A.M. 2007. Gait characterization and classification in horses. The Journal of Experimental Biology 210. 187-197.

Roepstorff, L. 2011-03-22. Personal message.

Starke, S.D., Robilliard, J.J., Weller, R., Wilson, A.M., Pfau, T. 2008. Walk-run classification of symmetrical gaits in the horse: multidimensional approach. Journal of royal society Interface 6, 335-342.

Zips,S., Peham, C., Scheidl, M., Licka, T., Girtler, G. 2001. Motion pattern of the toelt of Icelandic horses at different speeds. Equine vet. J., Suppl. 33, 109-111.