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Influence of palmarly added weights on locomotor parameters of the tölt of Icelandic Horses and comparison with corresponding data of the flying pace

Sara Boehart[1], Helmut Marquis[2], Parvis Falaturi[2] and Bianca Carstanjen[3]

Tierarztpraxis zum Sophienberg, Wensin, Germany[1], Marquis Tiermedizintechnik GmbH, Steinheim, Germany[2] and Department of Large Animal Diseases, Warsaw University of Life Sciences, Warsaw, Poland[3]

Summary

The aim of this study was to investigate the changes in kinematic and timely characteristics of the toelt of Icelandic Horses induced by the addition of weights applied to the palmar aspect of the hooves of the forelimbs. These effects were then compared with those seen in flying pace by use of the same weights, recorded in a preceding study. Six Icelandic Horses were ridden in a medium speed tölt, once without and once with added weights. Force at impact, force at end impact, force at lift off, cycle duration, stance phase duration, swing phase duration, duty factor, ipsilateral and diagonal overlap were recorded using computerkinematographic devices on the metacarpal and metatarsal region of both forelimbs and the right hindlimb. Data were analyzed using a generalized linear model, type III sums of squares to determine F- and p-values, with significance threshold of $p \leq 0.05$, post-hoc analyses were performed as t-tests over least square means. Mean values with standard deviations could be obtained. Following parameters were influenced significantly: force at impact, stance phase duration, swing phase duration and duty factor in the hindlimb, force at end impact in both forelimbs. The changes found resulted in a shift of the rhythm of the gait from a pacy tendency towards a clearer four-beat. The finding of significant changes in the kinematic parameters might implicate a higher risk of injury with the use of weights through higher accelerations acting on the musculoskeletal apparatus.

Keywords: Icelandic Horse / toelt / biomechanics / weight / gait analysis

Einfluss von Ballengewichten auf biomechanische Parameter des Tölts von Islandpferden im Vergleich mit entsprechenden Daten des Rennpasses

Die Studie befasst sich mit den Veränderungen kinematischer und zeitlicher Charakteristika des Tölts von Islandpferden durch Ballengewichte. Die Ergebnisse sollen mit im Rennpass beobachteten Effekten verglichen werden, die unter Verwendung derselben Gewichte in einer vorhergehenden Studie ermittelt wurden. Sechs Islandpferde wurden im Mitteltempo Tölt auf gerader ebener Strecke geritten, einmal ohne und einmal mit zusätzlichen Gewichten an den Vorderbeinen. Die aufgezeichneten Parameter sind die Beschleunigungen im Moment des ersten Bodenkontaktes des Hufes, im Moment des vollständigen Bodenkontaktes des Hufes und im Moment des Abhebens des Hufes vom Boden, die Dauer eines gesamten Bewegungszyklus, die Dauer der Stütz- und der Schwungphase, der Prozentsatz des Bewegungszyklus, den der Huf in Bodenkontakt ist, sowie die Dauer der Überschneidung der ipsilateralen und diagonalen Stützbeinphasen der Vorder- und Hintergliedmaßen. Die Daten wurden mithilfe computerkinematographischer Sensoren aufgenommen, die lateral am Metacarpus beider Vorderbeine und dem lateralen Metatarsus des rechten Hinterbeines mittels Bandagen fixiert wurden. Die Daten wurden mittels eines generalisierten linearen Modells analysiert, F- und p-Werte wurden mit Typ III Quadratsummen ermittelt mit einem Signifikanzniveau von <0.05. Post-hoc Analysen wurden als t-Tests über Least-Square-Mittel durchgeführt. Mittelwerte und Standardabweichungen wurden ermittelt. Folgende Parameter wurden signifikant verändert: bezüglich des Hinterbeines Beschleunigung beim Auftreffen des Hufes auf den Boden, Dauer der Stützphase, Dauer der Schwungphase und der Prozentsatz der Dauer der Stützphase am Gesamtzyklus, bezüglich der Vorderbeine die Beschleunigung im Moment des Auftreffens des Hufes auf den Boden. Die aufgezeichneten Veränderungen führten zu einer Verschiebung des Taktes von einer pass-artigen Tendenz, in der die laterale Zweibeinstütze betont ist, hin zu einem klareren Viertakt. Die signifikante Beeinflussung der kinematischen Parameter durch die Ballengewichte könnte aufgrund der größeren Kräfte, die auf das muskuloskeletale System einwirken, ein höheres Verletzungsrisiko implizieren.

Schlüsselwörter: Islandpferd / Tölt / Biomechanik / Gewichte / Ganganalyse

Introduction

The two gaits discussed in this study are unique to fivegaited Icelandic Horses, which are able to perform them next to the walk, trot and canter/gallop. The tölt is a four-beat gait preserved in some gaited horse breeds, including the Icelandic Horse. The gait is characterized by a footfall pattern similar to the walk, but with alternating phases of one or two limbs in contact with the ground simultaneously. It allows the rider to sit very comfortably with less concussion than the trot. The speed can range from very slow, collected to fast and extended (*Feldmann* et al. 1997a).

The flying pace in contrast is a lateral two beat gait with a marked suspension phase in between both ipsilateral limbs touching the ground simultaneously. In the Icelandic Horse the gait is only ridden at racing speed with a noticeable extension throughout the whole body of the horse (*Feldmann* et al. 1997b).

The use of weights to enhance the quality of the gait, which is judged by the rhythm of movement, elasticity of the horse and the height of the forelimb flight arc during the swing phase and in flying pace also the speed, is common in the Icelandic

Horse. The rules for Icelandic Horse competitions allow as much as 250g per leg added to the pastern respectively hoof region of the front limbs next to the shoeing (FEIF 2012).

In recent years different aspects of the gait and the effects of the use of these weights have been focussed on in research projects. One of the first studies concerning the tölt of Icelandic Horses was set up to establish stride characteristics and kinematics of three different speeds of the tölt and it was found that a true tölt was only detectable over a narrow speed range, with the extended speed tending towards a four-beat pace or rarely to a four-beat trot (*Zips* et al. 2001).

Another research group looked into the kinetics of the gait, evaluating the ground reaction forces in one study (*Biknevicius* et al. 2004) and determined the tölt to be a gait with bouncing mechanics and therefore classified it as a running gait (*Biknevicius* et al. 2006).

In order to classify gait patterns biomechanically using accelerometers mounted on the dorsal hoof wall and to evaluate a new device, the walk, trot, canter, tölt and flying pace of Icelandic Horses were recorded (*Robilliard* et al. 2007). Gait symmetry was measured by comparison of stance phases of the individual limbs, the percentage of the stance phase and the suspension phase in relation to the whole motion cycle. The tölt was classified as a symmetric gait.

In another setup, the influence of speed and weight addition on the motion of the limbs during tölt was investigated by kinematic analysis, testing at two different speeds and two different weights (170g, 280g) applied to the hooves of the forelimbs (*Rumpler* et al. 2010). Higher values were found at higher speed as well as with application of heavier weights, both conditions significantly changing the potential energy. Significant positive correlations were found between the height of the flight arc of the fore-but not of the hindlimbs and the speed as well as the weights, and furthermore between the minimum angle of the forelimb fetlock and carpal joints and both factors tested, but these were not significant.

A second study was published that used the setup described above (*Pecha* et al. 2011). The aim of the project was to establish the relationship between speed and weight application on the one hand and beginning and the duration of stance phase on the other. The authors stated an overall decreased tendency to show pronounced ipsilateral stance phase, but they also found marked individual differences in response to weight application and speed.

The authors of the present study carried out a second set of trials focussing on the changes in locomotor parameters of the flying pace by application of palmar weights to the forelimbs using the same study population and setup (*Boehart* et al. 2012). Overall, the generation of a greater uniformity of the gait was seen, but similar to the aforementioned study (*Pecha* et al. 2011) distinct individual differences were found. These seemed to be most pronounced in horses less experienced in performing the flying pace.

The present study was carried out to first establish mean values and their standard deviations for the different parameters evaluated and to discern the influence of palmarly added weights to both forelimbs on those in a medium speed tölt. In a second step the findings of this setup were compared to the results of a similar study concerning the flying pace (*Boehart* et al. 2012) carried out using the same horses and equipment as in this study. The findings of these two projects are intended to further the knowledge about these special gaits and to gain insight into the consequences of the weighting of the distal forelimbs.

Material and methods

Six trained five-gaited Icelandic Horses, aged five to 16 years (mean±standard deviation (SD), 9.29±4.31 years); three geldings, one mare, two stallions; height at the withers 1.34 to 1.52 m (1.43±0.09 m); body weight 254 to 386 kg (328.14±52.35 kg), measured with a measuring tape (Horse and Pony height-weight tape, Feeding and Conditioning Guide, The Coburn Company, Inc., Whitewater, USA) were ridden by one experienced professional rider down a 100m long straight track with a firm surface. The horses were shod with standard iron shoes on all for limbs, with 8mm thick shoes all around. Only clinically normal horses without any signs of musculoskeletal disorders were included. The project was approved by the Animal Care and Welfare Committee of Schleswig-Holstein in Germany.

The setup of this study was the same as of the study carried out by the same authors concerning locomotor parameters of the flying pace (*Boehart* et al. 2012) with the different gaits recorded on two following days with the same horses and rider involved.

The procedure for the data collection in the tölt differed insofar from that of the flying pace that each horse took four laps, two only wearing protective material and two with the weighted boots. The more uniform one of each category was chosen for evaluation, with the lap during which the horse wore only protective material was defined as lap 1, the other one with the weighted boots was defined as lap 2. The tölt was ridden at a medium speed (mean 5.932 m/s ± 0.026). Throughout the whole measuring procedure the horses were equipped with computerkinematographic sensors (marquis®CKG, marquis® Tiermedizintechnik GmbH, Steinheim, Germany; weight 150 g, size 90x60x35 mm) on the lateral aspect of the metacarpal respectively metatarsal area of all four limbs. The sensors detect axial accelerations in the direction of movement of the metacarpus respectively metatarsus. Standard bandages (Stallbandagen, Eskadron, Werther, Germany; weight 30 g) were used to hold the sensors in place.

Data were processed and evaluated using DIAdem 11.10f3806 TDM (National Instruments Ireland Resources Limited, Newbury, Ireland) and windows Excel (windows Microsoft® Office Excel® 2007 SPS MSO, Microsoft Corporation, Redmond, Washington, USA).

The data collection and analysis followed the same scheme as developed for the aforementioned study. Fourteen consecutive strides from each lap were chosen for evaluation. Data were collected for three limbs: the left (LF) and right (RF) forelimb and the right hindlimb (RH). Only one hindlimb was chosen for evaluation in order to use it for the determination of ipsilateral and diagonal overlap values. For this study only kinematic and timely variables were recorded. The kinematic variables are force at impact (FI), force at the end of impact (FEI) and the force at lift off (FLO) and are measured as multiples of the gravitational acceleration [g] in relation to the distal limb. The timely parameters consist of the cycle duration (CD), which lasts from the moment of impact until just before the next impact, stance phase duration (Stance PD), the duration of ground contact during one cycle of movement, and swing phase duration (Swing PD), which in contrast is measured from the moment just after lift off until the next moment of impact. All of the timely variables are recorded in seconds [s].

Three more parameters were derived from the timely data, the ipsilateral (Ipsilateral OL) and the diagonal overlap (Diagonal OL), which both are also recorded in seconds [s], and the duty factor (DF), that is given as the percentage of the full cycle duration that each hoof spends on the ground, i.e. the stance phase [%]. Ipsilateral OL and Diagonal OL define the time that the ipsilateral respectively diagonal pairs of limbs spend simultaneously on the ground.

Statistical analysis was done using SPSS (SPSS for Windows Version 17, SPSS Inc., Chicago, Illinois, USA). A linear mixed model was applied, with fixed effects and the random factor horse. The influence of the parameters leg and lap and also their interaction on the variables FI, FEI, FLO, CD, Stance PD Swing PD and DF were analyzed. Type III sums of squares were used to obtain F- and p-values, with the significance threshold set at 0.05. Mean values and respective standard deviations were obtained by post-hoc analysis through t-tests over least square means.

The above described procedure was then repeated for the variables Ipsilateral OL and Diagonal OL.

Results

The mean values and their standard deviation that were assessed in this study for the different parameters concerning each leg and each lap are given in Table 1 and 2. Considering the influence of the addition of palmar weights on the parameters the following findings were made:

- For FI, the only significant difference between the values for the two laps was found for RH ($p = 0.013$), with higher values seen during lap 2. The values for the front limbs only showed a non-significant tendency towards increased accelerations acting on them.
- The values for FEI differed significantly for LF ($p = 0.028$) and RF ($p = 0.015$), the value for RH was only non-significantly higher.
- For FLO and CD no significant influences by the weights could be detected, in contrast to Stance PD ($p = 0.005$), which was shorter during lap 2, Swing PD ($p = 0.001$), that in contrast was longer during lap 2, and DF ($p = 0.022$) with smaller values for lap 2. For these three parameters the figures for PD were always affected significantly by the weights.

- Concerning the overlap, Ipsilateral OL of the tölt was not significantly changed by the weights, but slight decrease in overlap time was noted. Diagonal OL was not significantly altered when looking at all six horses together.

Discussion

When comparing the findings of the two studies performed by the authors, it can be noted that some of the variables tested were changed in both gaits, but more changes are seen in the flying pace. This might be due to the higher velocity of the gait, resulting in a potentiation of the effect of the weights following the physical principle F = m x a. The phenomenon of a greater influence of weights at higher speeds was also noted by other authors (*Rumpler* et al. 2010, *Pecha* et al. 2011). Another explanation could be the fact that during the tölt always at least one hoof is touching the ground, whereas in the flying pace a clear suspension phase is evident. This could contribute to a greater fulcrum of the limbs around the body and therefore a higher resulting acceleration.

In both gaits an influence on the parameters recorded for the hindlimbs was noted, even though the weights were only applied to the hooves of the forelimbs. This effect was observed in a higher number of variables in the tölt than in the flying pace recordings, with even more parameters influenced significantly in the hind- than in in the forelimbs. This might be due to a shift of the carriage of the whole body by the horse from the fore- to the hindlimbs, resulting in higher loading forces respectively higher forces acting on them. When comparing joint work and power in the fore- and hindlimbs of horses during the trot, it was noted that the forelimbs generally have a net braking force, whereas the hindlimbs display a net propulsive force (*Dutto* et al. 2006) In a study looking into the energetic and kinematic effects of weights applied to the distal limb it was found that the range of motion only increased in the hind- but not in the forelimbs (*Wickler* et al. 2004). Even though in that study all four limbs were loaded equally, the change in biomechanics could resemble those found in the present study. Further research would be needed to look into this effect more deeply.

In the tölt a clearly longer ipsilateral than diagonal overlap was recorded, without as well with the added weights, resembling a deviation of an even four-beat towards a more pacy rhythm. The difference between the mean values for ipsilateral and diagonal overlap decreased when comparing lap 1 and lap 2. When looking at the data of each horse inividually, the diagonal overlap decreased in all but one horse when looking at the data of each horse individually, which suggests that the application of weights might emphasize the laterality of the gait.

This tendency towards pronunciation of the ipsilateral phase of the gait was also noted by other authors (*Zips* et al. 2001), who found that a true tölt is only shown at a very narrow speed window.

In the flying pace a tendency towards a prolongation of the lateral overlap during the lap with added weights was obser-

Table 1 Mean values ± standard deviations (X±SD) of parameters tested evaluated in relation to leg and lap in Icelandic Horses ridden at a medium speed tölt. / *Mittelwerte ± Standardabweichungen (X±SD) der untersuchten Parameter in Bezug auf Bein und Lauf von im Mitteltempo Tölt gerittenen Islandpferden*

Leg	Lap No.	FI (X±SD)	FEI (X±SD)	FLO (X±SD)	CD (X±SD)	StancePD (X±SD)	Swing PD (X±SD)	DF (X±SD)
LF	1	-3.322±0.092	5.625±0.145	5.431±0.200	0.482±0.005	0.280±0.005	0.202±0.004	58.152±1.182
	2	-3.420±0.094	5.890±0.405	5.659±0.218	0.480±0.008	0.282±0.008	0.197±0.006	59.012±17.360
RF	1	-3.681±0.112	5.650±0.191	5.853±0.236	0.482±0.024	0.285±0.035	0.197±0.015	58.953±1.175
	2	-3.821±0.122	5.945±0.205	6.029±1.060	0.480±0.008	0.282±0.008	0.198±0.008	58.953±14.016
RH	1	-0.543±0.157	5.982±0.120	2.226±0.144	0.480±0.006	0.403±0.119	0.077±0.003	84.145±1.326
	2	-0.760±0.144	6.136±0.947	2.456±0.159	0.479±0.004	0.390±0.006	0.089±0.004	81.481±1.021

LF: left forelimb, RF: right forelimb, RH: right hindlimb, Lap No. 1: horse wearing only protective material, Lap No. 2: horse wearing weighted boots, FI:force at impact [g], FEI: force at end impact [g] , FLO: force at lift off [g], CD: cycle duration [s], Stance PD: stance phase duration [s], Swing PD: swing phase duration [s], DF: duty factor [%], n=6 Icelandic Horses

LF: linke Vordergliedmaße, RF: rechte Vordergliedmaße, RH: rechte Hintergliedmaße, Lap No. 1: das Pferd trägt Schutzmaterial, Lap No. 2: das Pferd trägt Ballengewichte, FI: Beschleunigung im Moment des Auftreffens des Hufes auf den Boden [g], FEI: Beschleunigung im Moment des vollständigen Kontaktes des Hufes mit dem Boden [g], FLO: Beschleunigung im Moment de Abhebens des Hufes vom Boden[g], CD: Dauer eines Bewegungszyklus [s], Stance PD: Dauer der Stützphase [s], Swing PD: Dauer der Schwungphase [s], DF: prozentualer Anteil der Stützphase an der Dauer des gesamten Bewegungszyklus [%], n=6 Islandpferde

Table 2 Mean values ± standard deviations (X±SD) for the ipsilateral and diagonal overlap of the right side of the body (ipsilateral OL) respectively the right hind and the left forelimb (diagonal OL) and lap in Icelandic Horses ridden at a medium speed tölt /
Mittelwerte ± Standardabweichungen (X±SD) der ipsilateralen und diagonalen Überschneidung der Stützphasen der rechten Körperseite (ipsilateral OL) beziehungsweise der rechten Hinter- und des linken Vordergliedmaße (diagonal OL) pro Lauf von im Mitteltempo Tölt gerittenen Islandpferden

Lap No.	Ipsilateral OL (X±SD)	Diagonal OL (X±SD)
1	0.309±0.008	0.135±0.008
2	0.300±0.011	0.134±0.007

Lap No. 1: horse wearing only protective material, Lap No. 2: horse wearing weighted boots:, Ipsilateral OL: ipsilateral overlap [s], Diagonal OL: diagonal overlap [s], n=6 Icelandic Horses

Lap No. 1: das Pferd trägt Schutzmaterial, Lap No. 2: das Pferd trägt Ballengewichte, Ipsilateral OL: ipsilaterale Überschneidung der Stützphasen der Vorder- und Hintergliedmaße, Diagonal OL: diagonale Überschneidung der Stützphasen der diagonalen Vorder- und Hintergliedmaße, n=6 Islandpferde ved (*Boehart* et al. 2012), whereas in the tölt it was very slightly decreased by the weights. This discrepancy might be due to the difference in the gait patterns, another reason could be again the aforementioned higher speed during the flying pace, which might increase the impact of the weight on the limb function and timing of the different phases of the motion cycle.

Among Icelandic Horse riders empiric experience seems to point at a greater use of weight addition in the frontlimbs when the horse is showing a rather „pacy“ tendency, whereas adding weight to the hindlimbs improves the rhythm of the gait when dealing with a „trotty“ horse, in which the diagonal overlap is more pronounced (*Feldmann* et al. 1997a). Since the horses used in this study all showed a tendency towards a longer ipsilateral than diagonal overlap, this hypothesis can only be supported in so far that the difference between the duration of ipsilateral and diagonal overlap seemed to decrease with the addition of weights as mentioned above. But again it has to be emphasized that the findings varied among the horses, so a general statement cannot be made at this point regarding the correct placement of weights in relation to the shift in rhythm. Further research in this direction will be needed.

The cycle duration tended to be shorter during lap 2 in the tölt, resulting in more motion cycles during the same time period with DF staying nearly the same in the forelimb whereas it decreased significantly in the hindlimb, which is also reflected in the shortening of Diagonal OL by the weights in most horses and the slight decrease in Ipsilateral OL. Since the values for the hindlimb DF generally were recorded to be much higher than those seen in the forelimbs this significant shortening reflects a shift towards a more uniform beat. This tendency towards a more even rhythm by the addition of the weights was also seen in other studies (*Rumpler* et al. 2010, *Pecha* et al. 2011).

Looking at the kinematic parameters – i.e. FI, FEI and FLO – all where increased by applying the weights, some of them significantly. In the study focussing on the flying pace a similar development was noted with even more parameters being influenced significantly (*Boehart* et al. 2012). This increase of accelerational impact on the limbs by the application of weights might lead to detrimental effect on musculoskeletal structures due to altered strains acting on them. Furthermore, an earlier fatigue of the limbs and associated structures might occur through the higher metabolic costs of the added weight. The energetic consequences of weighting the distal limb where investigated (*Wickler* et al. 2004) and an increase of 6.7% of the metabolic rate was found after application of 600 g to the P3 region of all four limbs. These authors as well as others (*Pecha* et al. 2011, *Rumpler* et al. 2010) also assume a possible detrimental effect of the added weights on the musculoskeletal system and a higher risk of injury.

Both aspects should be kept in mind when starting a training of short duration as well as permanent use of weights in Icelandic Horses. Further studies looking into these aspects are warranted to give a definitive answer to the question about the consequences of weight use on orthopedic health in Icelandic Horses.

Conclusion

Conclusively, the application of weights on both forelimbs changed some of the parameters tested significantly, a finding that was more pronounced in the flying pace than in the tölt. The fact that the hindlimb values were altered more often than those of the forelimbs needs to be further investigated. The increase in kinematic accelerations at the different phases of the motion cycle might exert detrimental effects on the musculoskeletal system, which has also been suggested by other authors but also requires further research.

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Prof. Dr. Bianca Carstanjen PhD
Warsaw University of Life Sciences
Nowoursynowska St. 166
02-787 Warsaw – Poland
bcarstanjen@web.de