Journal of
Animal Physiology and Animal Nutrition

DOI: 10.1111/jpn.12155

ORIGINAL ARTICLE

Effect of different head–neck positions on physical and psychological stress parameters in the ridden horse

A. Zebisch[1], A. May[2], S. Reese[3] and H. Gehlen[1]

1 Department of Veterinary Medicine, Equine Clinic, Free University Berlin, Berlin, Germany
2 Faculty of Veterinary Medicine, Equine Clinic, Ludwig Maximilians University of Munich, Munich, Germany, and
3 Department of Veterinary Sciences, Faculty of Veterinary Medicine Ludwig Maximilians University of Munich, Munich, Germany

Summary

Different head–neck positions (HNPs) are used in equestrian sports and are regarded as desirable for training and competition by riders, judges and trainers. Even though some studies have been indicative of hyperflexion having negative effects on horses, this unnatural position is frequently used. In the present study, the influence of different HNPs on physical and psychological stress parameters in the ridden horse was investigated. Heart rate (HR), heart rate variability (HRV) and blood cortisol levels were measured in 18 horses. Low frequency (LF) and high frequency (HF) are power components in the frequency domain measurement of HRV which show the activity of the sympathetic and parasympathetic nervous system. Values were recorded at rest, while riding with a working HNP and while riding with hyperflexion of the horse's head, neck and poll. In addition, rideability and behaviour during the different investigation stages were evaluated by the rider and by an observer. Neither the HR nor the HRV showed a significant difference between working HNP ($HR = 105 \pm 22$/min; $LF/HF = 3.89 \pm 5.68$; $LF = 37.28 \pm 10.77\%$) and hyperflexion ($HR = 110 \pm 18$; $LF/HF = 1.94 \pm 2.21$; $LF = 38.39 \pm 13.01\%$). Blood cortisol levels revealed a significant increase comparing working HNP (158 ± 60 nM) and hyperflexion (176 ± 64 nM, $p = 0.01$). The evaluation of rider and observer resulted in clear changes of rideability and behavioural changes for the worse in all parameters collected between a working HNP and hyperflexion. In conclusion, changes of the cortisol blood level as a physical parameter led to the assumption that hyperflexion of head, neck and poll effects a stress reaction in the horse, and observation of the behaviour illustrates adverse effects on the well-being of horses during hyperflexion.

Keywords hyperflexion, head–neck position, stress, training, animal welfare

Correspondence H. Gehlen, Department of Veterinary Medicine, Equine Clinic, Free University Berlin, Oertzenweg 19b, 14163 Berlin, Germany. Tel: +49 30 83862299; Fax: +49 30 83862529; E-mail: gehlen.heidrun@vetmed.fu-berlin.de

Received: 13 July 2012; accepted: 12 November 2013

Introduction

Horses have been used for riding purposes for many centuries, and, through the ages, the idea of the desirable head–neck position (HNP) for special athletic aims has changed elementarily. Horses used for their pulling and carrying capacity were more or less allowed to move in a natural way. During the alterations in use to riding, the impact of halter, bridle and bit has been optimised increasingly, and now, the HNPs of ridden horses can differ considerably from the natural position (Meyer, 2006).

A specific training method, hyperflexion of head, neck and poll, the so-called rollkur, has been widely discussed in the equestrian world over recent years (McGreevy et al., 2010). The Code of Conduct of the International Equestrian Federation (FEI) was released in 1990 and states that 'all riding and training methods must take account of the horse as a living entity and must not include any technique considered by the FEI to be abusive' (Atock and Williams, 1994). When the horse is in hyperflexion, it has its head, neck and poll in a deep and round position (Van Breda, 2006), and the rider has more control over the horse than in any other HNP. The classic model states that the highest point in the ridden dressage horse should be the poll (Meyer, 2008), nevertheless, many riders nowadays use hyperflexion as a training method. The FEI, being conscious of the problems, tries to control the training methods carefully. Even though hyperflexion of the neck and poll has not been abused, it was stated that techniques for stretching the horse's poll must not be used aggressively or with force (International Equestrian Federation, 2010). A real prohibition or authorisation is very difficult to obtain as there is not enough scientific data to reach a final decision.

It is the aim of the present study to figure out the influence of the HNP on physical and psychological stress parameters in the ridden horse.

Materials and methods

Horses

A total of 18 horses with different genders were involved in the study presented. There were four stallions, nine geldings and five mares aged between four and 21 years old (9 ± 5). There were 17 Warmbloods and one Andalusian. Eleven of them were dressage horses, six were jumping horses and one was used for both. All horses were used to classic training methods, and not to hyperflexion.

Schedule of events and procedures

The investigation was divided into three stages. The first stage was an examination at rest (a), the second stage involved riding with a working HNP (b) and the third stage implied riding with hyperflexion (c; Fig. 1). The investigations at rest were performed in a stall with a halter before other manipulations were performed. The horses were walked out for 10 min before the riding programme for the study was started. The horses were then ridden for 15 min in the corresponding position for both stages, one half of the time at a trot and the other half of the time at a gallop. The study was conducted on two consecutive days at the same time and with the same protocol. For the working HNP, the horses were ridden with their nose line slightly before or on the perpendicular with the poll as the highest point. For the hyperflexion position, the horses were ridden in a low position with the maximum of possible flexion of head, neck and poll. The hyperflexion position was controlled by the rider through the reins, and the rider aimed at riding the horses at a constant speed in the different gaits. Six horses were ridden by a professional, and the other 12 horses by an 'up to highest level' successful amateur.

Blood cortisol

Three blood samples for the investigation stages were taken from the external jugular vein of each horse after skin disinfection with septoderm disinfectant (Dr. Schuhmacher GmbH, Melsungen, Germany) and with the help of sterile single hypodermic needles (BD Microlance, 18 G 2″, 1.2 × 50 mm, Heidelberg, Germany), immediately after exercise. A resting sample was taken in the stall, and the other two samples were obtained as soon as the different working stages were completed. The blood obtained was centrifuged directly after withdrawal at 3024 *g* for 10 min. The serum thus obtained was put into serum tubes and frozen immediately at −20 °C. This procedure was necessary to keep the cortisol levels in the blood stable. The serum was kept safe in a frozen condition until it was evaluated in a laboratory.

Electrocardiography

Digital electrocardiograms recorded by a telemetry Electrocardiography (ECG) (Televet 100; Kruuse, Marslev, Denmark) were obtained for each of the three examination stages. Consequently, three electrodes had to be placed on the horse: The first one was attached to the sternum, the second one to the left thoracic wall and the third one between the first and the second electrode. Signals were transferred via

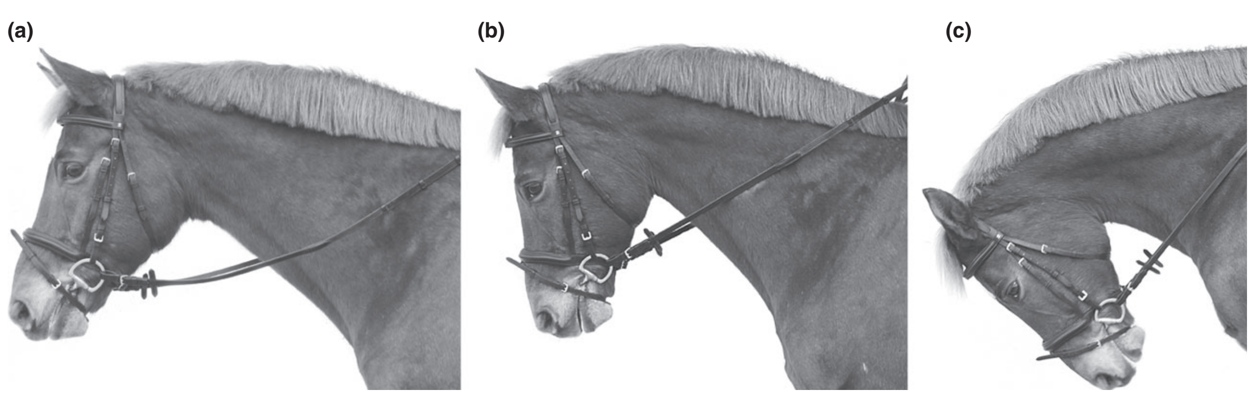

Fig. 1 Images of horses with the three different head–neck positions(HNPs): rest position (a), working HNP (b) and hyperflexion (c).

bluetooth to a laptop where they were saved. An ECG sequence free from artefacts was carried out for 120 s and analysed for each of the three examination stages. The sequences evaluated for stages 2 and 3 were chosen corresponding to the completion of the riding programme. The analysis was conducted with a special software program which allowed further processing of the data, as described in the following section (Televet – 100 Software version 4.1.3; Rösch Company & Associates Information Engineering GmbH, Frankfurt/Main, Germany).

Heart rate variability analysis

Txt.files were created out of the ECG files by heart rate variability (HRV) analysis software (Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland) for the time and frequency analysis. These txt.files showed the RR intervals measured in milliseconds. This was carried out by RR interval analysis with the software Televet (Televet – 100 Software version 4.1.3) after visual inspection. The limits established for the horse, especially between Low frequency (LF) and high frequency (HF) components, are considered in the program. The limit for LF was 0.01–0.07 Hz and that for HF was 0.07–0.6 Hz (Bowen and Marr, 1998; Kuwahara et al., 1998). Low frequency and HF are power components which show the behaviour of the two branches of the autonomic nervous system in the frequency domain measurement of HRV. The HF value reflects the parasympathetic activity. It decreases in anxiety, stress and strain. The LF value is influenced both by sympathetic and parasympathetic activity. It increases with exertion or stress (Task Force of the European Society of Cardiology and North American Society of Pacing and Electrophysiology, 1996). An interpolation of the RR interval time series and a fast Fourier transform (FFT) was made to determine the frequency range parameters. The FFT is a mathematical process that converts time-based data into frequency-based data. Here, the time series is represented as a sum of sine waves of different frequency and finally forms a so-called power spectrum. The sympathetic and parasympathetic components of the autonomic nervous system can be attributed to different components of the frequency range received.

In the study presented, the mean Heart rate (HR) and the mean RR interval were used as time-related parameters. The LF power, HF power and the ratio of LF/HF were used as frequency-related parameters. The LF/HF ratio reflects the sympathovagal balance. LF and HF were both evaluated in ms^2 and percentages (Task Force of the European Society of Cardiology and North American Society of Pacing and Electrophysiology, 1996).

Rideability and behaviour

After completion of the riding programme, the rider and an additional observer, who was an equine veterinarian and experienced rider, received a questionnaire for each horse which they answered independently. Based on a score, it was comparatively assessed how much effort was needed to ride the horse in hyperflexion, whether and what type of strain and/or defensive reactions of the horse could be perceived, how the horse behaved generally in the various HNPs and whether changes in the horse's behaviour during the stages were observed. The observer's parameters in detail were facial pain, tail swishing, tenseness, defensive movements, mastication and suppleness. The rider, furthermore, evaluated the reaction to riding aids and the rideability in general, that is how willing and cooperative the horse was, whether it was able to adjust to the new and different riding style and whether it responded to the best of its ability.

Statistical analysis

Commercially available software (SPSS 17.0; SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. The data were tested for normality by the Kolmogorov–Smirnov test adapted by Lilliefors (Lilliefors, 1967). All values are presented as arithmetic mean and standard deviation.

Differences between the blood cortisol levels, HR and HRV parameters were tested by the *t*-test for paired samples. The Wilcoxon signed rank test was used in the case of a significant difference to a normal distribution and to test differences in rideability and behaviour. A p-value <0.05 was considered significant.

Results

Blood cortisol

There was a rise of blood cortisol level from rest compared to the working HNP, but the difference was not significant (Fig. 2). The blood cortisol level was significantly higher at hyperflexion (176 ± 64 nM) than at a working HNP (158 ± 60 nM, $p = 0.01$). Furthermore, a significant correlation between cortisol increase in hyperflexion and the age and training level was demonstrated ($p = 0.018$). The older horses that were trained at higher levels tolerated hyperflexion less and had a higher increase in cortisol levels.

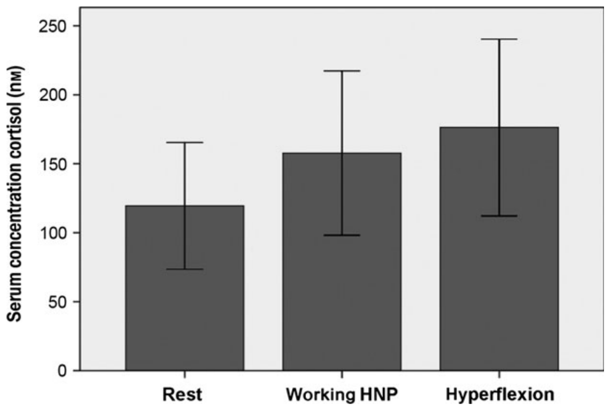

Fig. 2 Cortisol levels in the blood of horses (*n* = 18) in rest position, after riding with a working head–neck position and after riding with hyperflexion of head, neck and poll.

Electrocardiography

The HR did not show a significant difference between working HNP (105 ± 22/min) and hyperflexion (110 ± 18/min). There was a significant difference, an increase, between the first investigation stage and the others.

Heart rate variability analysis

Most of the parameters examined did not reveal significant differences between hyperflexion and working HNP. The LF/HF ratio showed a mean of 13.11 ± 23.28at rest, 3.89 ± 5.68 in the classic working HNP and 1.94 ± 2.21 in hyperflexion. LF showed a mean of 39.89 ± 5.32% at rest, 37.28 ± 10.77% in working HNP and 38.39 ± 13.01% in hyperflexion. Only the HF value indicated a significant difference (p = 0.011) between rest (11.11 ± 10.65%) and hyperflexion (25.61 ± 15.67%). However, there was no significant difference between the rest and the working HNP (22.06 ± 15.95%).

Rideability and behaviour

After the rider's evaluation, all parameters in terms of rideability collected between working HNP and hyperflexion had declined with a significant difference (Fig. 3). These parameters were the effort to ride the horse in hyperflexion (p = 0.005), act of mastication (p = 0.006), tenseness (p = 0.004), the effort necessary to ride the horse on the bit (p < 0.001), reaction to riding aids (p = 0.005) and the rideability in general (p = 0.001).

From the perspective of the observer, all parameters of the working HNP collected had improved

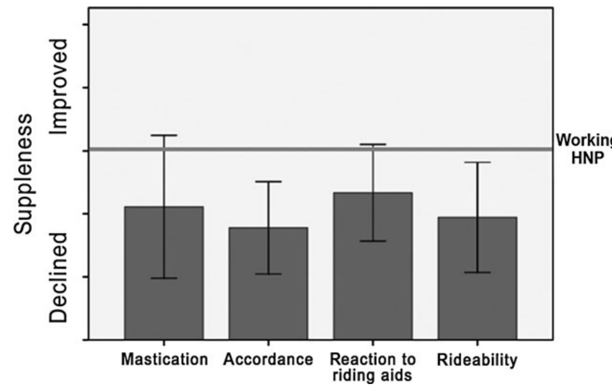

Fig. 3 Evaluation of rider's questionnaire.

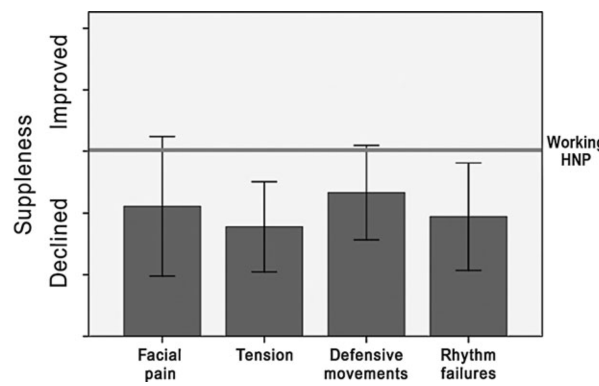

Fig. 4 Evaluation of observer's questionnaire.

(decreasing score values) compared to hyperflexion with a significant difference (Fig. 4), that is the aspects facial pain (p = 0.001), tail swishing (p = 0.002), tenseness (p = 0.003), defensive movements (p = 0.001), mastication (p = 0.004) and suppleness (p = 0.003).

Discussion

In the study presented, it has been investigated whether there is an influence of different HNPs on stress parameters in the ridden horse and whether there are differences in the behaviour of the horses when they are ridden with two different HNPs.

The HNPs used in the study have already been explained and examined in studies published a few years ago. In a study conducted by Rhodin et al. (2005), effects of various HNPs on the kinematics of the spine were investigated. Here, the horses were taken in the lower and higher position using side reins, while the third position was a free, natural head and neck posture (Rhodin et al., 2005, 2009). In the following time period, a more precise definition of various HNPs was obtained in some other studies. These studies made the understanding and further research on the topic easier by describing and examining several different HNPs (Gomez Alvarez et al., 2006; Weishaupt et al., 2006; Waldern et al., 2009). In the present study, positions for the different investigation stages were aligned to the positions defined here. The rest position corresponds to the HNP 1 = free and natural, with loose reins, the working position corresponds to the HNP 2 = poll as the highest point, the nose line slightly in front of the vertical and hyperflexion corresponds to HNP 4 = neck deep and low, poll flexed, nose line considerably behind the vertical.

In the present study, the horses were ridden without draw or side reins, thereby a less secure setting of the HNPs was possible, and there was an influence of the rider that otherwise had not been taken into account. In this way, a more realistic situation was created which was almost equivalent to a normal training situation and resembled the situation a horse has to cope with in 'normal' hyperflexion training. The effect of the rider has not been investigated previously in this way. In a study by Becker-Birck et al. (2013), horses were lunged with different HNPs, and physiological parameters did not indicate an acute stress response. In the present study, active intervention of the rider indicates that it is a stressful experience for the horse. Further studies should be performed taking a larger number of horses into account to find out more about the impact of the rider's interaction on the horse's welfare.

Several scientific studies have been carried out in the past few years to evaluate whether hyperflexion leads to physical or psychological stress in horses (Sloet van Oldruitenborgh-Oosterbaan et al., 2006; Van Breda, 2006; Von Borstel et al., 2009; Van Dierendonck et al., 2011).

A study from 2006 compares workload and stress in horses ridden in hyperflexion with draw reins and horses ridden with only a light rein contact in a natural position (Sloet van Oldruitenborgh-Oosterbaan et al., 2006).The workload was detected by HR and lactate concentration in the blood. Furthermore, packed cell volume, pH of the blood, bicarbonate concentration, partial pressure of CO_2, glucose concentration, activity of creatinine kinase and electrolyte content were part of the measurement. As a well-established stress parameter (Pell and McGreevy, 1999), serum cortisol concentration was also measured. Based on this study, cortisol levels in blood were also measured in the study at hand. According to the study by Sloet van Oldruitenborgh-Oosterbaan et al. (2006), the fact that blood cortisol concentration can be influenced by other factors must be considered. Its concentration is not only subject to psychological or physical stress, but also to a circadian rhythm (Irvine and Alexander, 1994). In the present study, the horses were undergoing various stages of investigation on consecutive days. To reduce the influence of the circadian rhythm, they were always ridden at the same time of the day. Cortisol concentrations evaluated in stall before the beginning of the riding programme made sure that the horses' cortisol levels were not altered by a circadian rhythm. In the study by Sloet van Oldruitenborgh-Oosterbaan et al. (2006), a difference in cortisol concentration could not be detected. However, a higher HR and higher lactate levels were found in horses ridden in hyperflexion in comparison with horses that were ridden in a natural position. In the present study, an increase in blood cortisol level from the resting stage to the working HNP was found, but it was not significant and could be explained by the increased physical load. The rise from rest to hyperflexion and also from working HNP to hyperflexion showed a significant difference.

The increase in HR from resting stage to the other stages of investigation reported here was associated only with the onset of physical activity. There was no significant difference between working HNP and hyperflexion.

Another study compared the stress levels of horses that were ridden in hyperflexion to horses carrying the head and neck in a natural posture (Van Breda, 2006). Heart rate variability as a stress parameter was used similarly to the present study. HR variability is an accepted parameter for stress and well-being of the horse and has often been used in scientific research (Kato et al., 2003; Rietmann et al., 2004). Only well-trained dressage horses were used in the group of horses which were ridden in hyperflexion, while the other group consisted of recreational horses (Van Breda, 2006). Similar to the study presented, no significant differences in HRV were found between the different HNPs. Van Breda (2006) found that training itself was more stressful for the recreational horses than riding in hyperflexion was for the dressage horses. Van Breda (2006) concluded that the study was not demonstrative yet, especially because no observation of behaviour was carried out. An objective system regarding the behaviour classification is needed to determine pain and discomfort in the horse (Rietmann et al., 2004). Therefore, questionnaires were distributed both to the rider and to an objective observer to obtain references of the horses' well-being in the present study. To receive even more objective results than in the comparison between leisure horses and dressage horses accustomed to training, in the study presented, all horses underwent both HNPs.

A study that attempted to measure the stress in horses by means of observation and creation of an ethogram came to the conclusion that behaviour problems occurred significantly more often while riding in hyperflexion than in normal HNP (Von Borstel et al., 2009). More tail swishing, attempted bucks and head tossing were seen while undergoing hyperflexion. Therefore, it was concluded that the horses feel more discomfort and frustration in the hyperflexion posture. In addition, it was easier to motivate the horses to go forwards when they had a natural HNP (Von Borstel et al., 2009). As McGreevy (2004) has already described, the author believes that the horses are confused by the fact that they are simultaneously being given a sign for going forwards by the legs and a sign for stopping by the reins. This might also be due to the fact that the horses in the present study were not used to being ridden in the hyperflexion posture. Similar parameters were observed and evaluated in the present study. Again, it can be concluded that behavioural problems, which show stress and discomfort, occurred significantly more often during hyperflexion than during working HNP.

Limitations

The HNP has not been fixed in our horses, and there was also no objective speed control; thus, we have no standardised positions and speed during our examinations. The rider always tried to manage the horses in the same way and at the same speed. However, there are, of course, differences to be expected in velocity and HNP between each horse. The reason for this was that we wanted to use normal riding equipment and procedures to reduce the additional factors which may cause stress in the horses. The study results, therefore, are not directly comparable to studies performed on a treadmill, but they provide additional information regarding the effects of neck hyperflexion in a natural riding environment.

Horses with a very supple poll may occasionally remove their nose behind the vertical in the working position if the driving aids and the reins are not entirely balanced, for instance, if the horse wants to go faster than the rider allows and the rider tries to control speed with the reins. This position is not correct in the classical sense, but there are important differences to hyperflexion: i) the neck remains in the normal position compared to a low position in hyperflexion and ii) the position of the nose is not intentionally enforced by very strong aids.

Our study does not run in a crossover design, and we only took one cortisol blood sample after exercise. Cortisol concentrations are affected by a large variety of factors, and cortisol can also be released due to physical activity alone. In our study, we worked the horses only moderately to see more effects of the HNP instead of exercise on the stress parameters. The lack of cortisol increase in the control (non-hyperflexed) group indicates that no real physical activity was required from the horses. Thus, the differences should mostly be induced by other factors which are mainly stress-induced by head hyperflexion.

The rideability was only judged subjectively by an observer and the rider himself. We did not find an objective method for this parameter.

Conclusion

In conclusion, it can be said that hyperflexion led to a significant increase in cortisol, which can be interpreted as a sign of stress. The older and better-trained horses showed a greater increase than the younger ones. Furthermore, the behaviour observed and the rideability became significantly worse during hyperflexion. The various parameters show that hyperflexion leads not only to physical, but also to psychological stress. Further studies are needed to expose the influence on performance and on long-term effects.

Acknowledgement

The authors are grateful to Dr. Senckenberg, Bavarian State Stud, for the help with the study and provision of the horses.

References

Atock, M. A.; Williams, R. B., 1994: Welfare of competition horses. *Revue Scientifiqueet Technique* **13**, 217–232.

Becker-Birck, M.; Schmidt, A.; Wulf, M.; Aurich, J.; von der Wense, A.; Möstl, E.; Berz, R.; Aurich, C., 2013: Cortisol release, heart rate and heart rate variability, and superficial body temperature, in horses lunged either with hyperflexion of the neck or with an extended head and neck position. *Journal of Animal Physiology and Animal Nutrition* **97**, 322–330.

Bowen, I. M.; Marr, C. M., 1998: Analysis of heart rate variability in horses with ventricular arrhythmias. *Proceedings of the 37th British Equine Veterinary Association Congress, Birmingham.*

Gomez Alvarez, C. B.; Rhodin, M.; Bobbert, M. F.; Meyer, H.; Weishaupt, M. A.; Johnston, C.; van Weeren, P. R., 2006: The effect of head and neck position on the thoracolumbar kinematics in the unridden horse. *Equine Veterinary Journal. Supplements* **36**, 445–451.

International Equestrian Federation (FEI), 2010: FEI stewards manual dressage, Annex XIII.

Irvine, C. H. G.; Alexander, S. L., 1994: Factors affecting the circadian rhythm in plasma cortisol concentrations in the horse. *Domestic Animal Endocrinology* **11**, 227–238.

Kato, T.; Ohmura, H.; Hiraga, A.; Wad, S.; Kuwahara, M.; Tsubone, H., 2003: Changes in heart rate variability in horses during immersion in warm spring water. *American Journal of Veterinary Research* **64**, 1482–1485.

Kuwahara, M.; Hiraga, A.; Nishimura, T.; Tsubone, H.; Sugano, S., 1998: Power spectral analysis of heart rate variability in a horse with atrial fibrillation. *Journal of Veterinary Medical Science* **60**, 111–114.

Lilliefors, H., 1967: On the Kolmogorov–Smirnov test for normality with mean and variance unknown. *Journal of the American Statistical Association* **62**, 399–402.

McGreevy, P. D., 2004: *Equine Behaviour, a Guide for Veterinarians and Equine Scientists*. Saunders, Elsevier Limited, London.

McGreevy, P. D.; Harman, A.; McLean, A.; Hawson, L., 2010: Over-flexing the horse's neck: a modern equestrian obsession. *Journal of Veterinary Behaviour* **5**, 180–186.

Meyer, H., 2006: Die natürlichen Kopf-Hals-Positionen des Pferdes und ihre Veränderungen durch den Menschen. *Pferdeheilkunde* **22**, 694–697.

Meyer, H., 2008: *Rollkur– Die Überzäumung des Pferdes*. Wu Wei Verlag, Schondorf, Germany.

Pell, S. M.; McGreevy, P. D., 1999: A study of cortisol and beta-endorphin levels in stereotypic and normal thoroughbreds. *Applied Animal Behaviour Science* **64**, 81–90.

Rhodin, M.; Johnston, C.; Roethlisberger Holm, K.; Wennerstrand, J.; Drevemo, S., 2005: The influence of head and neck position on kinematics of the back in riding horses at the walk and trot. *Equine Veterinary Journal* **37**, 7–11.

Rhodin, M.; Gomez Alvarez, C. B.; Byström, A.; Johnston, C.; van Weeren, P. R.; Roepstorff, L.; Weishaupt, M. A., 2009: The effect of different head and neck positions on the caudal back and hindlimb kinematics in the elite dressage horse at trot. *Equine Veterinary Journal* **41**, 274–279.

Rietmann, T. R.; Stauffacher, M.; Bernasconi, P.; Auer, J. A.; Weishaupt, M. A., 2004: The association between heart rate, heart rate variability, endocrine and behavioural pain measures in horses suffering from laminitis. *Journal of Veterinary Medicine Series A: Physiology, Pathology, Clinical Medicine* **51**, 218–225.

Sloet van Oldruitenborgh-Oosterbaan, M. M.; Blok, M. B.; Begeman, L.; Kamphuis, M. C. D.; Lameris, M. C.; Spierenburg, A. J.; Lashley, M. J. J. O., 2006: Workload and stress in horses: comparison in horses ridden deep and round ("rollkur") with a draw rein and horses ridden in a natural frame with only light rein contact. *Tijdschrift voor Diergeneeskunde* **31**, 114–119.

Task Force of the European Society of Cardiology and North American Society of Pacing and Electrophysiology, 1996: Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation* **93**, 1043–1065.

Van Breda, E., 2006: A nonnatural head-neck position (Rollkur) during training results in less acute stress in elite, trained, dressage horses. *Journal of Applied Animal Welfare Science* **9**, 59–64.

Van Dierendonck, M. C.; Sleutjens, J.; Wijnberg, I.; Back, W.; van der Kolk, H. J., 2011: The effect of different head and neck positions – including hyperflexion – on the behavior of base-level warm blood riding horses during moderate exercise.*Journal of Veterinary Behaviour* **6**, 296–297 (Abstract).

Von Borstel, U. U.; Heatly Duncan, I. J.; Shoveller, A. K.; Merkies, K.; Keeling, L. J.; Millman, S. T., 2009: Impact of riding in a coercively obtained rollkur posture on welfare and fear on performance horses. *Applied Animal Behaviour Science* **116**, 228–236.

Waldern, N. M.; Wiestner, T.; von Peinen, K.; Gomez Alvarez, C. G.; Roepstorff, L.; Johnston, C.; Meyer, H.; Weishaupt, M. A., 2009: Influence of different head-neck positions on vertical ground reaction forces, linear and time parameters in the unridden horse walking and trotting on a treadmill. *Equine Veterinary Journal* **41**, 268–273.

Weishaupt, M. A.; Wiestner, T.; von Peinen, K.; Waldern, N.; Roepstorff, L.; van Weeren, R.; Meyer, H.; Johnston, C., 2006: Effect of head and neck position on vertical ground reaction forces and interlimb coordination in the dressage horse ridden at walk and trot. *Equine Veterinary Journal. Supplements* **36**, 387–392.