

# A note on the welfare implications of hyperflexion in the training of the ridden horse

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## Motivation

The Dutch Ministry of Agriculture, Nature and Food Quality has asked equine welfare scientists to give an update of the scientific studies on hyperflexion (or Rollkür) that have been published since the FEI Workshop in 2006 (FEI, 2006).

*".....In the letter the director of the Dutch Animal Welfare Organization points out that this is a missed opportunity for the horse sport sector to show it's serious intent with regards to the wellbeing of the horse. In the report resulting from the FEI workshop concerning hyperflexion it is noted that all professionals present were unanimously of the opinion that the horses cannot be forced with the use of the hyperflexion training method or any other training method.*

*At all times training methods should be applied correctly and the wellbeing of the horse be of the highest priority.*

*With this workshop the international horse industry shows that they are taking the responsibility towards this subject. This corresponds well to my policy that the wellbeing of animals is primarily the responsibility of the owner of the animal.*

*This is way I have asked the horse sector to set out an action plan to improve the wellbeing of horses. In this, training methods to be one of the four key focuses.*

*Portioning out the responsibility does however not dismiss me of my duty to following up on what has happened since this has been put forward. Hence I have asked the KNHS and scientists to lay out the insights and research that has been published since 2006 with regards to the wellbeing of horses in relation to hyperflexion and other training methods.*

*Gerda Verburg – Ministry Agriculture, Nature and Food Quality "*

The FEI defines hyperflexion as follows: "Hyperflexion of the neck is a technique of working/training to provide a degree of longitudinal flexion of the mid-region of the neck that cannot be self-maintained by the horse for a prolonged time without welfare implications." However, it does not provide a definition of welfare nor does it specify periods that are regarded as prolonged. Hyperflexion of the horse's neck is currently employed as a training method by a number of high-level competition dressage riders, and increasingly used by eventers and show-jumpers. That said, some degree of cervical hyperflexion is commonplace these days in many equestrian disciplines. For example, even during the training of Arabian horses for western pleasure, many are found to be slightly behind the vertical in a simple snaffle and martingale (Heleski personal communication).

The use of hyperflexion is controversial as it may adversely affect the horse's welfare by causing and being created as a result of discomfort (Von Borstel, 2007). It has also widely been used by professional show-jumpers, usually using draw reins, since the eighties. However, the more extreme forms of hyperflexion, in which the nose of the horse is pointing to the sternum (i.e., almost touching the pectoral region), became popular only during the last decade, especially in high level dressage training.

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<sup>1</sup> The ISES is a not-for-profit organisation that promotes and encourages the application of objective research and advanced practice to ultimately improve welfare of horses in their associations with humans. In doing so, one of the aims of the ISES is to provide a pool of expertise to national governments, international bodies, industry and to those equine welfare organisations which deal with problems involving equine behaviour, training and welfare (further details see [www.equitationsscience.com](http://www.equitationsscience.com))

There is still some confusion and apparently some disagreement between different authors concerning the name given to similar but not necessarily identical riding techniques that involve training the horse (in-hand or under saddle) with its nose behind the vertical. For example, other terms for hyperflexion include low-deep-and-round (LDR) and Rollkür. For the purpose of this report low-deep-and-round (LDR) and Rollkür will be regarded as forms of hyperflexion.

During the FEI workshop (2006), no evidence was shown that hyperflexion causes long-term *physical* damage. Moreover, it was hypothesized that hyperflexion may be beneficial for training as it was thought to have positive effects on the motility of the back, by simultaneously decrease in stride length and increase in range of motion (elasticity) (Van Weeren *et al.*, 2006). Conversely, Denoix (2006) pointed out that hyperflexion places stress on the intervertebral discs, in the nuchal area and at the withers that may cause pain in horses with pre-existing conditions. Despite the temporary airway convolution and visual impairment, horses may habituate to intense exercise with prolonged hyperflexion. Of course, this does not automatically mean that the practice is acceptable since many horses demonstrate outstanding behavioural flexibility and so often give the appearance of being able to tolerate unethical levels of confinement, pain and discomfort.

According to Heuschmann (2006), hyperflexion contains “an aggressive component that could have a negative effect on a horse’s movement compared to the acceptable and well-proven low-deep-and-round (LDR)”. In addition, several researchers have highlighted potentially deleterious effects of hyperflexion on the *psychological* state of the horse and hence ignore the horse’s ethological needs and violate the five freedoms of welfare<sup>2</sup> (Von Borstel, 2007). Ödberg (2006) suggested that coercive riding may be linked to so-called wastage, i.e. euthanasia/slaughtering of horses rendered unfit for ridden work or sport by physical and/or psychological problems.

The Veterinary and Dressage Committee of the FEI concluded that thorough investigation of hyperflexion is required and that there was a need for research that confirmed unequivocally whether or not there are welfare issues involved in training techniques using hyperflexion.

## Introduction

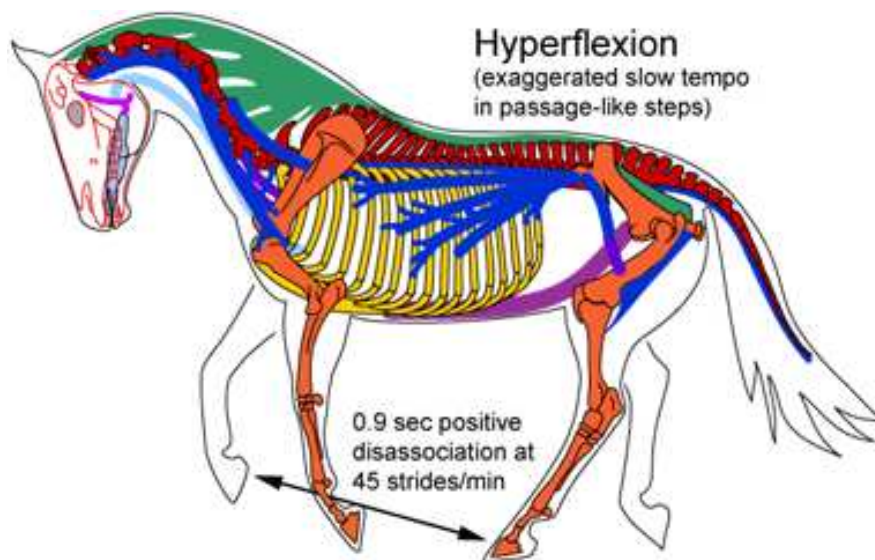
The aim of all training is to produce a horse that is useful and responsive to signals of the rider or trainer. For the horse to meet these conditions, its weight, plus that of its rider, must be correctly distributed over all four limbs. Naturally horses carry more of their weight on the fore limbs than on their hind limbs. In collection, the hind limbs flex more, stepping further underneath the horse in the direction of the centre of gravity, thereby taking a greater share of the load. This in turn lightens the forehand, allowing the forelimbs to move more freely (Rhodin, 2008).

Hyperflexion occurs when the rider causes the horse to flex its neck downwards and caudally, according to most authors, raising its back as a result. According to those who practice the technique, hyperflexion alternated with short periods of extension of the neck ventrally, stimulates the horse’s ventral muscles to contract. By doing so, the horse strengthens his ventral musculature and induces greater flexion of the hock joints and is therefore better to be able to carry out the required exercises specific to the sport of dressage. According to Rhodin (2008), this method puts tension on the dorsal neck muscles and the vertebral column. If hyperflexion is practiced such that the horse’s nose is directed to the sternum, the horse shows a broken neckline, a strongly (though incorrectly) raised back

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<sup>2</sup> Brambell committee (1965): The five freedoms are: 1) free from hunger, thirst and inadequate food 2) free from thermal and physical discomfort, free from injuries, illnesses and pain; 4) free from anxiety and (chronic) stress; 5) free to perform natural behaviours.

and a straight croup (Heuschmann, 2006)<sup>3</sup>. The trailing of the hind legs can be explained by the fact that the dorsal fascia connect with the large muscle groups of the hind limbs (Rhodin, 2008). See for example figure 1.



**Figure 1. Schematic representation of a horse in hyperflexion.**

If the horse has been forced to show this flexion by rein tension or resistance from the rider's hands when it attempts to extend its neck, it can do nothing more to relieve itself of the pressure in its mouth. This leads to deficits in training (i.e., the quality of the slow/stop/step-back response declines), subsequent conflict behaviours that result from the confusion and possibly learned helplessness where the animal superficially tolerates pain (McGreevy & McLean, 2007).

Most of the discussion in Lausanne related to positive and negative influences on different bony and soft tissue anatomical structures, it is worth bearing in mind that since the Lausanne meeting little attention was paid to the role of:

- airway convolution; additional to that described in all bitted horses by Cook (2000)
- visual impairment [hyperflexion severely restricts the horse's vision in the direction of travel (McGreevy, 2004)],
- learned helplessness (Hall et al. 2008) by possibly making the horses completely dependent on their riders for directing them
- confusion caused by violations of the basic principles of leaning theory (McLean et al., 2006)

### Scientific studies since Lausanne meeting 2006

Since the meeting of the FEI Veterinary and Dressage Committee in Lausanne, 2006, published work on physical and psychological effects of hyperflexion remains very scarce, primarily due to the virtual absence of dedicated funding but also due in part to ethical issues associated with applying aversive procedures in research. An additional impediment to

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<sup>3</sup> Dr Heuschmann has published a book on this subject in 2007 (Tug of war: classical versus "modern" dressage), but this book and his other writings are a reflection of very thorough, but not scientifically tested, observations. Therefore they will not be included in the later scientific discussion.

research is that horses available for research projects are unlikely to be of comparable quality to those competing at the upper levels.

**The following scientific studies have, to our knowledge, been published since the Lausanne meeting 2006 (details of the studies are summarized in table 1):**

Gomez-Alvarez et al. (2006)<sup>4</sup> performed kinematic studies in which horses previously trained in hyperflexion, were worked in-hand on a treadmill while maintaining five different head/neck positions and one control (unrestrained) position (Figure 2).

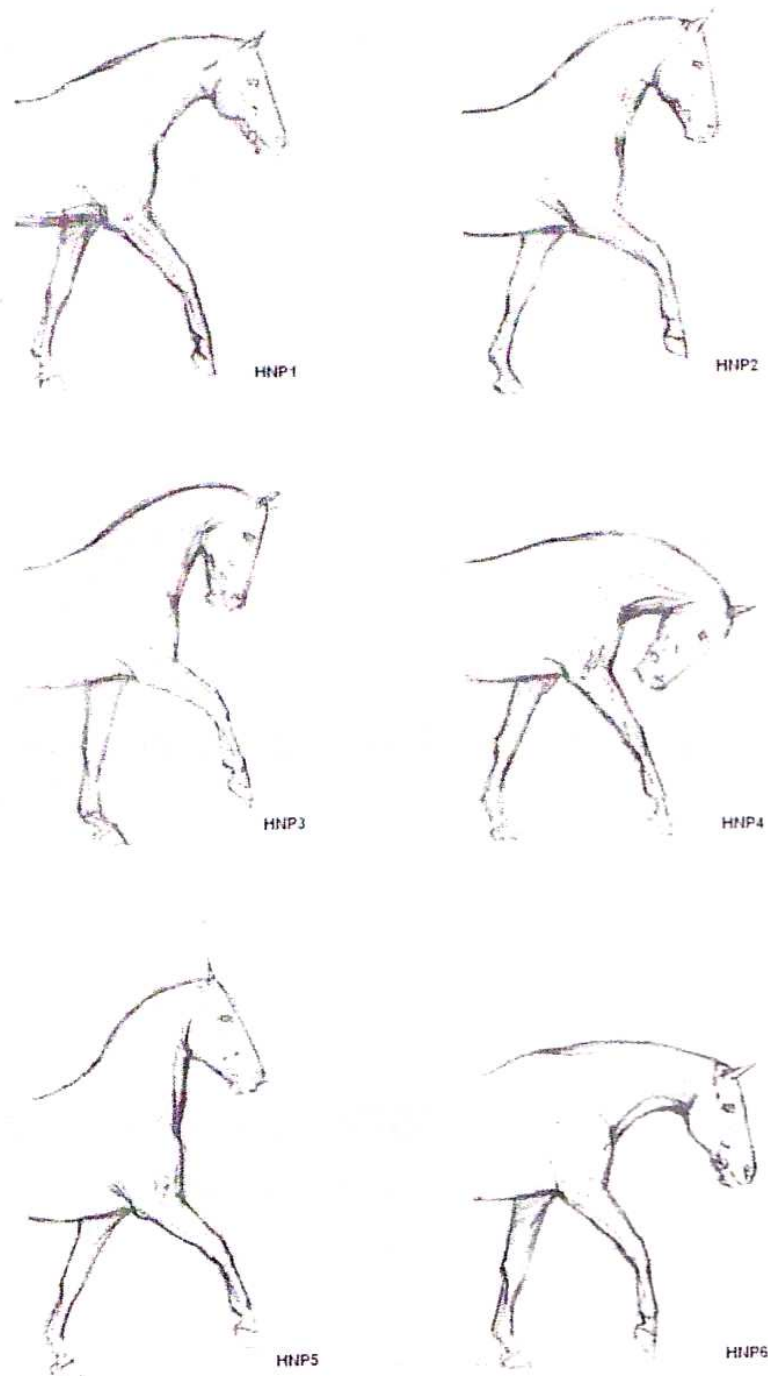
The following unstrained positions were used: HNP2=neck raised, bridge of the nose in front of the vertical; HNP3=as HNP2 with bridge of the nose behind the vertical; HNP4=head and neck lowered, nose behind the vertical; HNP5=head and neck in extreme high position, leading to extension of the ventral muscles; HNP6=head and neck forward downward. HNP1 was a speed-matched control (head and neck unrestrained). For comparison with the control (shape 1), the positions were chosen to show the effects of the head and neck being flexed as they are 'normal' training situations, including the competition position (2-3); hyperflexion (4); a very high position (5) and a low free shape (6).

"The positions in which the neck was extended (HNP2, 3, 5) increased extension in the anterior thoracic region but increased flexion of the thoracic and lumbar vertebral region. For HNP4, the pattern was the opposite. Positions 2, 3 and 5 reduced the flexion-extension range of motion while HNP4 increased it. HNP5 was the only position that negatively affected intravertebral pattern symmetry and reduced hind limb extension. Stride length at the walk was significantly reduced in positions 2, 3, 4 and 5" (Gomez-Alvarez et al., 2006). The authors concluded that head/neck position had a significant influence on lumbar kinematics. Elevated head and neck induced extension in the thoracic region and flexion in the lumbar region while also reducing the dorso-ventral range of motion of the vertebral column. Lowering of the head and neck produced the opposite. A very high position of the head and neck (position HNP 5) seemed to disturb normal kinematics. The authors further hypothesized that this study provided quantitative data on the effect of head/neck positions on motion of the vertebral column in the thoracic region and may help in discussions on the ethical acceptability of some training methods.

The authors made very thorough and valuable observations, but when looking at the absolute numbers it appears that, although significant, the reported differences were measured between several vertebrae and were so small that their biological relevance to the horse is debatable.

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<sup>4</sup> These results were presented in brief at the FEI workshop in Lausanne but the peer-reviewed paper was published later in the year 2006



**Figure 2. Head and Neck Positions (HNP) used in the study by Gomez et al (2006)**

Sloet van Oldruitenborgh-Oosterbaan et al. (2006) performed a study “to test the effect of riding horses low-deep-and-round (LDR) on workload and stress”. The horses in this study were not used to being ridden in this manner. Illustrative material from the study (Figure 3)

shows that the treatment resembled a posture in which the horses were ridden with the nose behind the vertical (comparable to HNP3 in Figure 2), but not with the chin onto the chest. Riders were not blind to the treatment and half of the horses started with a test in LDR, the other half of the horses in a test with a natural posture (comparable to HNP1 in Figure 2), with only light rein contact. During the tests horses were trotted and cantered for several minutes.



**Figure 3. A horse ridden “rollkür” (round and deep with a draw rein) in the study of Sloet van Oldruitenborgh-Oosterbaan et al. (2006)**

This study found higher heart rates and blood lactate concentrations in school horses during LDR posture, compared with when in a natural posture with light rein contact. However, the authors reported that subjective observations suggested improvement of movement during the treatment and, since they did not notice any signs of uneasiness in the horse, concluded that higher heart rates were a sign of higher workload during the LDR posture.

However, the variables used to measure stress during riding were limited to mean heart rate and blood parameters. It is known that mean heart rate is predominantly influenced by locomotion, and can in certain circumstances (i.e. sudden or new events) also have an emotional component (Visser et al., 2002). Unfortunately, the authors did not include measures for heart rate variability (HRV) in their study. This is an unfortunate omission because heart rate variability has been established a common measure for use in challenge tests for animals since it is less influenced than mean heart rate by locomotion. That said, Goodwin et al. (under review with Physiology and Behaviour) report HRV data from eight horses in two locomotory states that show poor correlation with simultaneously collected ECG data, thus questioning the usefulness of HRV data for all but stationary horses.

In the meantime, Van Breda<sup>4</sup> (2006) performed a study to measure the effects of hyperflexion training technique on stress parameters in elite, Olympic level, dressage horses in comparison with non-competition recreational horses. The hyperflexion position was induced in the Olympic level dressage horses without the use of draw reins for an average of  $24 \pm 6$  min during one training session, whereas it was never used for the non-competition recreational horses. The results showed that after one training session for the Olympic level

dressage horses had higher HRV (time and frequency domains) compared with the recreational horses. According to the author, this indicated that the Olympic level dressage horses did not experience more stress than the recreational horses.

Although this study did use HRV as a physiological stress parameter, it did not include behavioural observations. Moreover, in this experiment, HRV was measured 30-45 minutes after the training exercise after the horses had been washed and groomed. The HRV reported might have reflected these latter handling procedures instead of (or as well as) the training technique. Another limitation of this experimental design is that the riders were not blind to the treatments. Furthermore, in the paper it is claimed that "pain" was measured, but we are not able to draw the same conclusion from the presented data. Moreover, strong muscle pain cannot be excluded in these recreational horses, since they were not trained to work in this conformation. Furthermore, recreational riding can be stressful for other reasons (e.g., poor riding technique can create confusion and conflict).

Finally, where it was applied, hyperflexion was induced without the use of draw reins, so the horses were presumably already conditioned to respond to the hyperflexion cue - even though it conflicts with the cue to slow down, stop, step back - and so may have habituated to the confusion it can cause. McGreevy & McLean (in press) note that: "Horses that have been trained to shorten the neck are likely to offer this response when they are subjected to pressure from the bit. The problem is that the same or dangerously similar pressure from the bit should be *slowing* the horse. The result can be a horse with habituation to rein signals (i.e., a hard-mouthed horse)". Forcing the horse to bend its neck from rein pressure blurs the distinction between cues for stopping or simply bending the neck. This is because the rein cue to hyperflex is the same or is very similar to the cue for stopping while the denoted response is different, with the result that the 'stop' is detrained (McGreevy & McLean (in press)).

Von Borstel et al., (2009) assessed the impact of riding in a hyperflexed posture on welfare and fear of performance horses. For this study, they recruited riding horses naïve to hyperflexion. Horses were tested in a Y-maze apparatus. When leaving one arm of the Y-maze, they were ridden in round hyperflexed posture as long as they accepted it (when head tossing was too strong, the horse was given a very short break). When leaving the other arm of the Y-maze, it was ridden in regular poll flexion. After a training period of 30 times, horses entered the Y-maze and had to choose which arm to leave and subsequently either perform a circuit in hyperflexion or a circuit in a regular poll position. There were no differences in heart rates between treatments, but significantly more horses chose more often the maze arm associated with the regular poll flexion rather than that associated with hyperflexion. Conflict behaviours such as tail swishing and mouth opening were shown more often during the non-preferred hyperflexion option. Riders used the whip or kicked the horse significantly more frequently during the hyperflexion than in regular position, indicating that horses were more reluctant to move forward during the hyperflexed position. It was suggested that horses were more reluctant to move forward both because of their restricted vision and/or because of confusion with the stop signal. According to the authors, these findings indicate that a coercively obtained hyperflexion position may be uncomfortable for horses *unaccustomed* to it, and that it makes them more fearful and therefore potentially more dangerous to ride. The temporary visual impairment could be an alternative (or additional) explanation of the horses' apparent unwillingness to go forward.

Furthermore, there are other factors associated with riding, such as interspecific social interaction with the rider, or the horse's / rider's level of fitness which might have influenced the experience of horses during riding. It is possible that the exercise aspect of riding will, in combination with possible discomfort due to the rider's actions, over-ride any other potentially positive factors. It therefore seems likely in the choice situation that horses, unaccustomed to hyperflexion, avoided it rather than preferring regular poll flexion. Using operant tasks to investigate how hard horses are willing to work to avoid riding in regular and/or hyperflexed posture would potentially offer a more exhaustive assessment of horses' aversion to different riding styles.

A better experimental design would involve an even mix of horses used to being ridden in hyperflexed posture and used to being ridden in normal poll flexion. This was not possible because insufficient numbers owners of horses accustomed to hyperflexion could be recruited for this study. As it stands, this study leaves us wondering whether the relative aversion reflected the novel tension put on the muscle groups in the naïve horses because they were untrained in this position, or the position itself with all attendant challenges such as compromised vision and air-flow. Another limitation of this experimental design is that the riders were not blind to the treatments. It is possible that the riders in the present study gave subconscious (or even conscious) cues to the horses as to which maze arm to choose. Hence, an improvement would have been to use two different riders for the preference test: one (blinded to the treatments) who rode only the choice parts in the maze, the second who applied only the corresponding treatment once the horse had chosen one arm of the maze or the other. Unfortunately, the testing of physiological feedback parameters (such as circulating cortisol concentrations, HRV or any provocation tests) was negligible in this study.



**Table 1. Characteristics of the presented published studies (those marked with an asterisk were considered at the Lausanne meeting but have since been published in the peer-reviewed literature).**

Published studies since Lausanne workshop 2006	N (horses)	Background and breed of horses tested	Method / treatment groups	Conditioning method prior to test	Kinematic parameters	Behavioural parameters	Physiological parameters	Performance parameters	Conclusion by the authors in relation to hyperflexion
Gomez Alvarez <i>et al.</i> , 2006*	7	All high level dressage horses; warmblood	Unridden horses: walking and trotting on treadmill; five different head and neck positions plus control achieved using different side reins; observers were not blind to treatment	Horse were accustomed to treadmill locomotion with and without rider	Speed, angular motion patterns, asymmetry, variability, pro- and retraction of the limbs, linear stride parameters	none	none	none	Elevated head and neck induce extension in the lung region and flexion in the lumbar region; besides reducing the up-and-down range of motion. Lowered head and neck produces the opposite. A very high position of the head and neck seems to disturb normal kinematics.
Sloet van Oldruitenborgh-Oosterbaan <i>et al.</i> (2006)	8	All riding-school horses; Dutch warmblood	All horses were ridden in two tests: one without side reins and one with the use of side reins to achieve a hyperflexed posture; riders were not blind to treatment.	None of the horses was familiar with the use of side reins;	None	Subjective impression of state of relaxation	Mean heart rate (interval 15 seconds); blood samples: cortisol, creatine kinase, blood lactate, pH, pCO <sub>2</sub> , HCO <sub>3</sub> <sup>-</sup> , glucose, electrolytes, packed cell volume	Subjective impression of movements	Slight increased workload during hyperflexion and no signs of uneasiness or stress. Subjectively, all horses improved: their way of moving when an experienced rider rode them hyperflexed with a draw rein. Hyperflexion does not adversely affect the welfare of the horse provided an experienced and knowledgeable rider practices it with care.
Van Breda (2006)*	12	recreational horses (n=7) and elite dressage horses (n=5); Dutch warmblood	Heart rate variability measures in the stable 30 minutes before and 30 minutes after training and care taking; no information how the hyperflexion posture in the training was induced; riders were not blind to treatment	Elite dressage horses were trained in hyperflexed position prior to the study, the recreational horses were not	None	none	Heart rate variability measured before training and 30-45 minutes after washing/grooming	none	Elite dressage horses trained according to the hyperflexion method suffered no more stress than did recreational horses based on heart rate variability results 30 minutes post exercise.
Von Borstel <i>et al.</i> (2009)	15	Privately owned (n=6) or school horses (n=9); representing show jumping (n=5), dressage (n=6) & both (n=4); warmbloods, different breeds	After conditioning phase in Y-maze, horses had to show a preference for one side or the other (Rolkür or normal collection); horses were confronted with a fear test ridden in Rolkür or normal collection; all horses were hyperflexed using draw reins; riders were not blind to treatment.	None of the horses had previous experience with hyperflexion;	None	Change of pace, backing up, crabbing, attempted bucks, stumbling, tail-swishing, head-tossing, nose-tilting, abnormal oral behaviour, snorting, groaning, visibility of eye white, ears fixed backward, rider uses whip or kicking	Mean heart rate (15 seconds interval)	Preference based on Y-maze test	Horses showed higher levels of discomfort when ridden in a coercively obtained hyperflexed posture compared with regular, moderate poll flexion, and that they will avoid being ridden in hyperflexion if given the chance.

## Discussion

One of the most striking findings from the current brief review is the apparent lack of fresh studies published since Lausanne. Indeed the take-home messages from two of the four studies reported here were considered at the Lausanne meeting. So it is disappointing to discover such an underwhelming response to the challenge set by the Lausanne workshop. Moreover, it is somewhat surprising that, in the intervening two years, the stated benefits of training horses in hyperflexion (both “at home” as well as during warming-up at elite competitions) have not been demonstrated with empirical data.

The concept of welfare is interpreted very differently from one research discipline to another. For example, in traditional veterinary science the emphasis has predominantly been on physical health, whereas in applied ethology physical and behavioural health are equally weighted. This dichotomy is reflected in the parameters chosen by the researchers to explore possible relationships links between the applied training techniques as well as the conclusions drawn in relation to welfare. So far, most studies have focused on the non-mental aspects of hyperflexion, i.e., on parameters such as kinematics, health and training-physiology. So, hardly any behavioral parameters have been included in these studies. Compared with physiological measures, motivational and preference tests can provide more direct insight into how an animal perceives certain conditions or treatments. These are especially important when attempting to interpret the mental consequences of training on welfare.

Another aspect that needs attention is the definition of hyperflexion itself. While most researchers and practitioners no longer use the term Rollkür, there remains a tendency among some trainers to regard LDR training as distinct. The distinction, if any between especially LDR and hyperflexion, is elusive.

Yet another aspect that differs between studies is critical one of whether the horses were ridden or not. Obviously the effect of the rider can have a variable influence on a range of parameters including kinematics, behaviour and physiology. Currently only the horses’ head and neck position achieved has been considered in the discussion of the welfare implications of hyperflexion. This may be too simplistic an approach. The manner in which this position is achieved should also be considered and standardised in future studies. Between the current four studies, the ways in which hyperflexion was achieved differed significantly. For example, some used draw reins and others did not. Therefore the findings of these studies are often not comparable with each other and require tremendously cautious extrapolation to the elite dressage context because practitioners can argue that their system of creating hyperflexion is entirely different to those applied during the studies. Shaping hyperflexion relies on some degree of rein tension regardless of whether draw (or side) reins are used. Horses not familiar with hyperflexion training will obviously show more aversive responses since their muscles are not used to stronger or longer contraction / extension, possibly resulting in muscle pain. Furthermore, these naive horses find bit pressure highly aversive; in many cases older horses show some degree of habituation and therefore require stronger rein tensions. This fortifies the argument for rein tensiometry in future studies to expose the accumulated effect of habituation when interpreting signs of tolerance.

Several of the studies in the current report used subjective observations to score responsiveness and often the effects have yet to be measured in the long term. Based on subjective observations, some authors suggest that hyperflexion (or the use of draw reins) have positive effects on the horse’s responsiveness to the rider and its movement (Sloet van Oldruitenborgh-Oosterbaan *et al.*, 2006; Gomez-Alvarez *et al* 2006). However, the apparent increase in responsiveness may well be an effect of the restricted vision in the hyperflexed posture, which makes the horse dependent on the rider’s cues to navigate.

Some aspects did not receive much attention in the latest research, even though they may have an important bearing on the perception of the horse. For example, hyperflexion most likely severely restricts the horse's vision in the direction of travel (McGreevy, 2004) and may also disturb the horse's biomechanical equilibrium (Ollivier, 1999; Karl, 2006). The possibility that these two impediments can lead to learned helplessness (LH) is still open to debate, but has not been seriously addressed by any study to date. That said, even though in any discipline, there may be certain high risk situations in training horses in which one could expect LH to occur, it is still not established if LH actually occurs in horses.

The confusion induced in the horse by applying one cue (pulling with both hands) for two responses (slowing/stopping versus flexing the neck) is a recognized cause of detraining in the horse. It can lead to a dangerous detraining of the deceleration response. Furthermore, the subsequent confusion can induce conflict resolution behaviours in horses. Horses seek to avoid pain. When they are prevented from doing so (e.g., when trapped between competing pressure from the riders' reins and legs), they sometimes become hyper-reactive, using *active* coping mechanisms. This can mean that even though they are actively trying to escape, escape is thwarted. This can prompt horses to escalate their active coping strategies such as causing them to trial hyper-reactive predator removal behaviours (such as bucking, rearing and shying) (McGreevy and McLean, in press). All these effects could possibly have psychological implications.

Further topics, from the riders' perspective have not yet been studied in detail. For example, some riders claim that this practice helps to stretch and strengthen the horse's back muscles and therefore prevents injuries (Passino, 2005).

### **Questions to be addressed**

Questions must be addressed before one can unequivocally confirm whether or not there are welfare issues involved in training techniques using hyperflexion. They include:

1. Although the FEI workshop has resulted in a universal definition of hyperflexion, the relation to and distinction with rollkür and low-deep-and-round (LDR) is still elusive. Is there a universal understanding among scientists, trainers and stewards of the relation to and distinction with these techniques and hyperflexion?
2. Does hyperflexion have a positive effect by improving lumbar and abdominal muscle development, greater hock flexion, fewer injuries in performing certain exercises?
3. How could it be determined how these techniques can be applied correctly (use rein tension meters, behavioural response of the horse)?
4. What is an optimal experimental design in terms of background of the horses (experienced/not experienced with hyperflexion and elite or schooling horses), conformation of horses in groups, control groups and conditioning phase? What are the limitations and advantages of each group? How can future experimental designs be standardized?
5. Over what period have study and competition horses been conditioned to the process? How long/how many training sessions does it take to train a horse to learn it? How long can it be performed (in one session) before it has a positive or negative (welfare) effect for the horse? And is it the result of unrelenting pressure?
6. How should hyperflexion be induced in an experimental set up to test the effect on welfare, bearing in mind that the cue for hyperflexion is the same or very similar to the one used to slow/stop/step back?
7. Do the perceived short term benefits of hyperflexion in terms of responsiveness persist in the long term? How is this measured objectively?
8. How is the welfare of the in-hand and ridden horse measured reliably and with which criteria?

For the practical implication on the training and competition grounds:

9. Who determines whether the technique is applied correctly (i.e. what are these persons' qualifications)?
10. What would be the typical resistances shown by the horses when being trained to hyperflex?
11. How do trainers interpret occurrences of tail swishing and mouth opening during the execution of hyperflexion training?
12. How do trainers interpret concurrent use of whip and spurring and leg pressure during hyperflexion training ?

It is clear that the parameters used in any study of ridden horse welfare have to combine well established behavioural, physiological (HR and HRV for instance), blood parameters (cortisol, lactate, O<sub>2</sub> etc.), anatomical (Rontgen, CT / MRI scans; EMG's) and physical (rein tensionmeters<sup>5</sup>, oesophageal pressure meters, kinematic) measurements. As it happens, a study including hyperflexion of ridden horses that includes many of the aforementioned techniques is being conducted in Utrecht at the Veterinary Faculty.

It is probably worth considering whether there can be good and bad hyperflexion, and whether rein tensiometry or a self-carriage test might be used to distinguish between them. From a behavioural perspective, the application of sustained pressure by the rider or relentless resistance from the horse amount to the same thing: pressure in the mouth, which can lead to habituation. Research is needed to remove emotiveness from the hyperflexion debate by establishing, for a range of equine athletes, how much contact is neutral, how much rein tension is too much, how discomfort and pain could be measured and how learned helplessness manifests itself in horses (McGreevy and McLean, 2007).

## General conclusion

Only a small handful of novel studies have been published since the 2006 Lausanne meeting on hyperflexion. Unfortunately, these studies have tended to be marred serious flaws in methodology, limited numbers or unhelpful parameters used. This leads us to conclude that there is still insufficient scientific evidence to confirm unequivocally whether or not there are welfare issues involved in training techniques using hyperflexion.

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<sup>5</sup> Rein tension measurements have been published and offer the simplest way of monitoring the buccal pressures required (either in one hit or by some accumulation of sustained smaller rein signals) to trigger hyperflexion

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