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Effects of the level of experience of horses and their riders on cortisol release, heart rate and heart-rate variability during a jumping course

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Abstract

Equestrian sports require the co-operation of two species, horses and humans, but it is unknown to what extent stress responses in the rider affect the horse. In this study, the stress response of experienced and less-experienced horses and riders at showjumping was analysed. Sixteen sport horses were divided into two groups (n = 8 each) by experience and were ridden by highly experienced professionals (n = 8) and less-experienced riders (n = 8). Riders jumped a course of obstacles with an experienced and a less-experienced horse and horses took part with an experienced and less-experienced rider. Salivary cortisol, heart rate and heart-rate variability (HRV) variables, standard deviation of RR interval (SDRR) and root mean square of successive RR differences (RMSSD) were analysed. Cortisol and heart rate increased and HRV decreased in all riders and horses. In less-experienced riders, cortisol release was higher on a less-experienced versus an experienced horse but the horses' cortisol release was not affected by experience of their riders. Heart rate did not differ between groups of horses and was not affected by experience of the rider but was higher in less-experienced versus experienced riders. The HRV decreased in horses and riders and SDRR was lower in less-experienced versus experienced riders. Thus, lower experience of riders appears not to affect physiological stress parameters in their horses during a showjumping course.

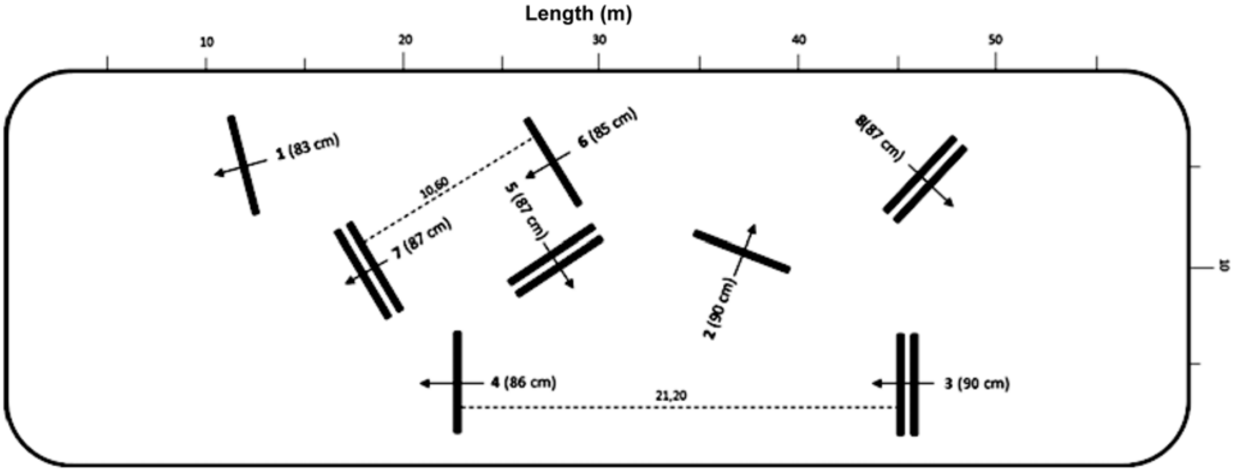
Keywords: *animal welfare, cortisol, heart rate, horse, rider, stress*

Introduction

Equestrian sports are not only associated with physical demands but may also induce a physiological stress response in horses (Schmidt *et al* 2010a; Becker-Birck *et al* 2012b) and their riders (Westerling 1983; Trowbridge *et al* 1995; von Lewinski *et al* 2013). Stimuli which are perceived as stressful initiate a hypothalamo-pituitary-adrenocortical and an adrenomedullary and sympathetic nervous system response. During short-term stress, as usually occurs in competitions, increasing cortisol release may improve fitness by energy mobilisation (Raynaert *et al* 1976) and changes in behaviour (Korte 2001). Non-protein-bound cortisol rapidly diffuses into saliva and salivary cortisol concentrations thus mirroring changes of free cortisol in blood plasma (Peeters *et al* 2011). Acute stress, as well as physical demand, elicit an immediate release of adrenaline and subsequent increase in heart rate. In exercising equine and human athletes, heart rate is influenced mainly by physical effort but also by emotional factors. Heart-rate variability (HRV), ie short-term fluctuations in heart rate, reflects the oscillatory antagonistic influence of the sympathetic and parasympathetic (vagal) branch of the autonomous nervous system on the sinus node of the heart (von Borell *et al* 2007). Heart-rate variability decreases to a certain degree with increasing heart rate (Hottenrott *et al* 2006) but because it reflects the vago-sympathetic balance, HRV also indicates the response of the autonomic nervous system to stress (von Borell *et al* 2007).

Equestrian sports require the close co-operation of two different species, humans and horses, which have to interact efficiently to achieve success in competitions. As in other sports, training and competitions elicit an acute stress response in horses (Schmidt *et al* 2010a; Becker-Birck *et al* 2012a,b) and riders (Westerling 1983; Trowbridge *et al* 1995; Devienne & Guezennec 2000). Only few studies have addressed the combined response of horses and humans to potentially stressful situations. In a preliminary study (Keeling *et al* 2009), anticipation of a flight response in horses to a not yet visible object led to increases in heart rate not only of the person leading the animal but also in the horses themselves. In contrast, riders, but not horses, in a public performance of classical dressage showed a more pronounced physiological stress response than in a training situation but the stress response of the riders was not trans-

Figure 1



The showjumping course with size of the arena, type and height of obstacles and distances between obstacles on a straight line indicated.

ferred to their horses (von Lewinski *et al* 2013). The physiological response of riders to an equestrian challenge is thus not only determined by the physical demands but also by their emotional state.

Stress in the horse or its rider may negatively affect the response of the horse-rider pair to external challenges and thus increase the risk of accidents. Sports-related injuries in riders are considerable in their severity (Lloyd 1987; Sørensen *et al* 1996; Thomas *et al* 2006). In a study on sports-related accidents in school-aged children in Denmark, 18% of the accidents in girls treated in an emergency hospital were related to riding or handling of horses with only handball having a higher accident rate (Sørensen *et al* 1996). Accidents are most frequent in young and inexperienced riders (Lloyd 1987). Horses are a prey species and can be 'spooked', ie in situations perceived as dangerous a flight reaction is initiated. Experienced riders may foresee and often prevent such situations, while the insecurity of less-experienced riders may further enhance anxiety in the horse, leading to accidents of horse and rider thus potentially affecting not only human health but also animal welfare. Research is therefore needed on the interactions of experienced and less-experienced riders with experienced and less-experienced horses. It is neither known to what extend the response of the horse to an equestrian challenge is influenced by experience of the horse itself and by its rider nor whether a less-experienced rider may enhance the horse's physiological stress response.

A showjumping course is a standardised task and allows the analysis of the response of horses and their riders to challenges in equestrian sports. We hypothesise that the challenges of a showjumping course elicit a stress response in the horse and its rider and this response in both species is affected by the level of experience of the horse and the person, respectively. Studying horse-rider pairs with different levels of experience also allows detecting interactive effects in the stress response of the two species. We thus also hypothesised that less-experienced riders increase the stress response of their horses to a standardised challenge. As physiological stress parameters, salivary cortisol concentrations, heart rate and HRV were determined.

Materials and methods

Horses and riders

For this study, 16 sport horses of the Brandenburg State Stud at Neustadt (Dosse), Germany were made available. Horses were divided into two groups by equestrian experience. All horses were male (three stallions and five geldings in each group). Horses of group 1 (n = 8) were classified as experienced in showjumping competitions. They were trained and had participated successfully in showjumping competitions at an advanced level in Germany (level S: at least ten obstacles; height 140–150 cm; width 150–200 cm). Mean (± SD) age of group 1 horses was 6.5 (± 0.9) years. Horses from group 2 (n = 8) had completed basic equestrian training and had not yet participated in any showjumping competitions. Mean (± SD) age of group 2 horses was 4.8 (± 0.8) years. All horses were kept in individual boxes on wood chippings or straw and fed concentrates and hay twice daily. Water was available *ad libitum*. All horses were trained 5–6 times per week and the horses of group 1 participated in competitions on a regular basis, ie 2–3 weekends per month. The riders who participated in the study were either professional riders trained to an advanced level, (group 1; n = 8, age 32 [± 6.9] years) or apprentices and riding students (group 2; n = 8, age 17.6 [± 2.1] years). All riders were male and all of them were riding on a regular basis (6–7 days a week and at least two horses per day). All riders and horses were familiar with the outdoor riding arena used for the study.

Experimental design

Horses and riders were studied before, during and after a standardised jumping course (Figure 1). All riders from groups 1 and 2 participated with an experienced (horse group 1) and a less-experienced horse (horse group 2). Thus, each horse took part twice, once with an experienced and once with a less-experienced rider. The order of rider-horse combinations was arranged in a double Latin square design, thus eliminating carry-over effects on the side of both horses and riders. The interval between the two tests in the horse and in the rider was always one day.

Experimental procedures

All tests were performed in the same outdoor riding arena and at the same time of the day (between 1400 and 1600h) and for all participants the same procedure was followed. On experimental days, the horses remained in their stable until the experiment and riders had to rest in the horse stable for at least 30 min prior to saddling their horse, mounting and then riding 'in walk' a distance of 400 m to the outdoor arena. There, the horses and riders warmed up 'in walk' (5 min), followed by trot (3 min) and canter (3 min). After this warm-up phase, they jumped two individual obstacles (numbers 2 and 5) at reduced height. This was followed by the jumping course which consisted of eight obstacles and was identical for all participating horse-rider pairs (Figure 1). After finishing the jumping course, riding was continued 'in walk' for five more minutes in the arena to cool down and then horses were ridden back to the stables where the riders dismounted. Saliva, for cortisol analysis, was collected repeatedly (see below) before and after riding from the horses and riders and heart rate was recorded continuously before, during and after riding. During recordings before and after riding, horses were kept in their familiar stable in individual loose boxes. With the exception of saddling their horses immediately before riding, riders spent the time before and after riding without any activity in a separate room adjacent to the stable. Horses, as well as riders, were monitored over the whole recording period to ensure that all study details were identical for all days.

Cortisol analysis

Saliva for determination of cortisol concentrations was taken at 30 and 15 min before riding and at 0, 15, 30 and 60 min thereafter. In the horses and riders, saliva was collected as described previously (Schmidt *et al* 2010a). Cotton rolls (Salivette, Sarstedt, Nümbrecht-Rommelsdorf, Germany) were placed loosely onto the tongue of the horse with the help of a surgical arterial clamp until the swab was well soaked within 1 min. Saliva collection was performed without restraining the horse. It did not cause any discomfort and was well tolerated by all horses. Riders placed the salivette into their mouth and gently chewed to stimulate salivation for approximately 1 min. The salivettes were then centrifuged for 10 min at 1,000 g and saliva was aspirated and frozen at –20°C until cortisol analysis. Concentrations of cortisol were determined with a direct enzyme immunoassay without extraction validated for equine saliva (Palme & Möstl 1997; Schmidt *et al* 2010a). Since the antiserum cross-reacts with cortisone and a number of cortisone metabolites, values have to be interpreted as cortisol immunoreactivity (IR). The intra- and inter-assay coefficients of variation were 5.0 and 6.7%, respectively and the minimal detectable concentration was 0.3 pg per well.

Heart rate and heart-rate variability

The cardiac beat-to-beat (RR) interval was recorded in the horses and riders with a mobile recording system (S810i, Polar, Kempele, Finland). Recordings in horses were performed as described (Schmidt *et al* 2010a,c) and recordings in riders followed the manufacturer's recommendations. Recordings were made for 1 h before riding, continuously during riding and for 1 h thereafter in the horses and the riders. Heart rate and the heart-rate variability (HRV) variables, standard deviation of RR interval (SDRR) and root mean square of successive RR differences (RMSSD) were calculated from the RR interval. The analysis of heart-rate variability was made with the Kubios HRV software (Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland). To remove trend components, data were de-trended and an artefact correction was made (Schmidt *et al* 2010b,c) following established procedures (Tarvainen *et al* 2002).

For comparisons of heart rate and heart-rate variability, 1-min intervals were selected from the warm-up walk, trot and canter phase, the jumping course and the cool-down walk phase. Additional 1-min intervals were analysed at 30 and 15 min before the riders mounted their horses and 15, 30 and 60 min after finishing the course, ie when riders had dismounted their horses.

Statistical analysis

For statistical analysis, the SPSS statistics package (version 17.0; SPSS, Chicago, IL, USA) was used. All data were normally distributed (Kolmogorov-Smirnov test). Changes in salivary cortisol concentrations, heart rate and HRV variables over time were analysed in horses and in riders by ANOVA using a general linear model for repeated measures with own level of experience and level of experience of the partner as between subject factors. A P-value < 0.05 was considered significant. All data given are means (± SEM).

Results

Cortisol

Salivary cortisol concentrations in horses and their riders increased significantly during riding and returned to baseline values about 30 min after the jumping course (changes over time: horses; $P < 0.001$, riders; $P < 0.01$; Figure 2). In the horses, the cortisol increase was neither affected by their own level of experience nor experience of their human partner while in the riders cortisol release in response to the equestrian tasks of the study was more pronounced in less-experienced versus experienced riders and more pronounced when riders were mounting a less-experienced horse versus an experienced horse (for riders time × experience; $P < 0.01$, and time × experience of the equine partner; $P < 0.01$).

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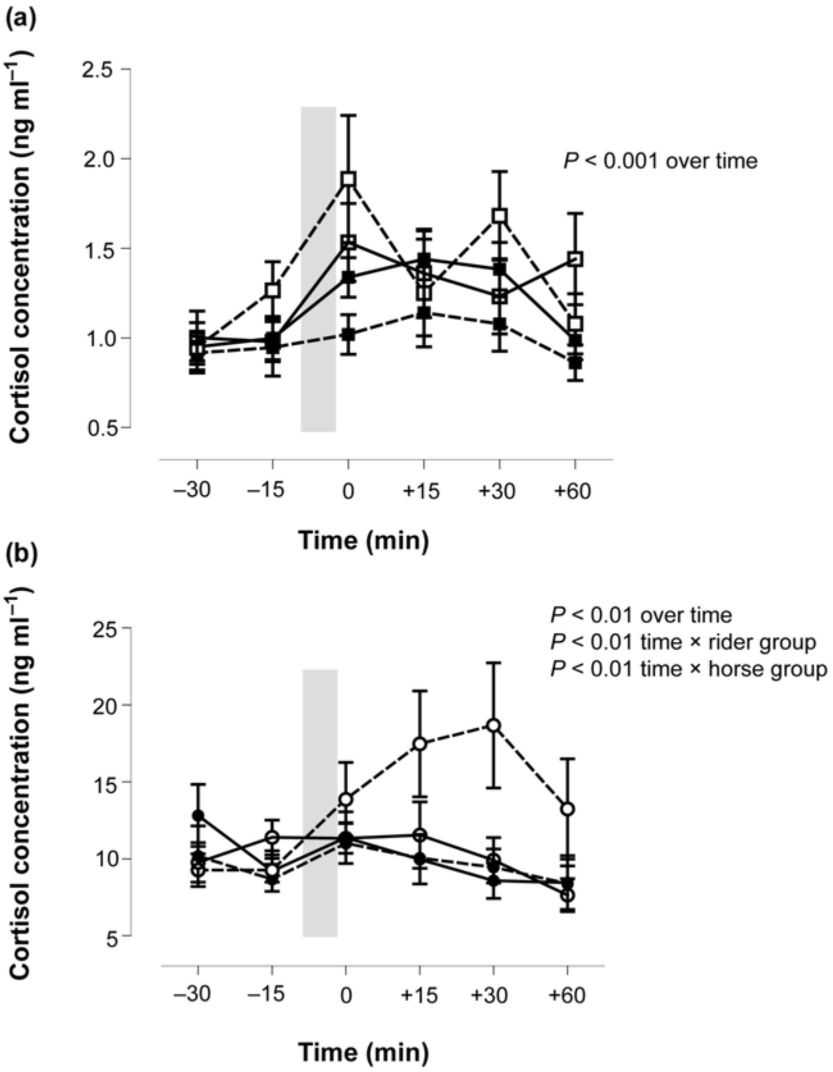
Figure 2



Cortisol concentrations before and after a standardised jumping course in (a) experienced (■) and less-experienced horses (□) and (b) experienced (●) and less-experienced riders (○) with experienced (continuous lines) and less-experienced (dashed lines) partners of the other species. Shaded bar = riding time. Note different scales on y-axis.

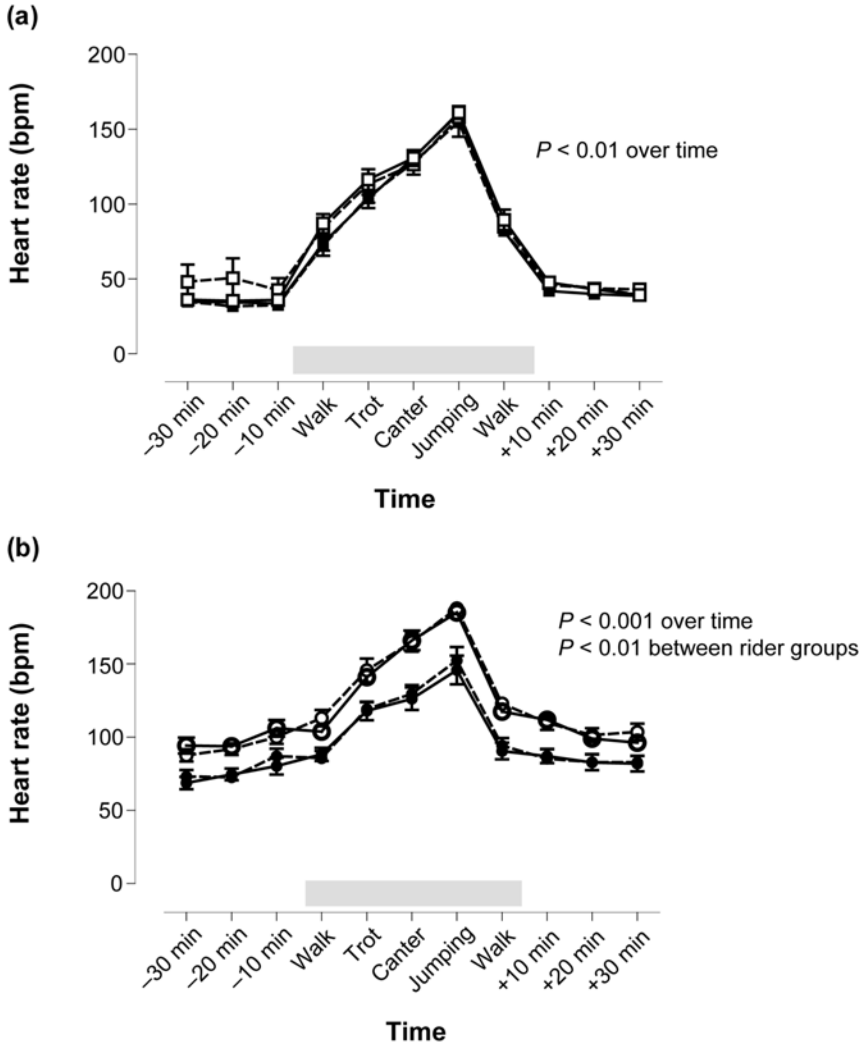
Heart rate and heart-rate variability

Heart rate increased significantly during riding in both species ($P < 0.001$). Heart rate in the horses increased continuously from walk to trot, canter and jumping but the heart-rate profile did not differ between experienced and less-experienced horses (experienced horses: maximum 160.6 [± 4.2], less-experienced horses: maximum 161.2 [± 4.2] beats min^{-1}) and was not affected by the experience of the rider mounting the horse (Figure 3[a]). Heart rate of less-experienced riders (group 2) was higher at all times than in experienced riders (group 1; differences between groups; $P < 0.001$, interactions time × group; $P < 0.001$; experienced riders: maximum 152.4 [± 9.1], inexperienced riders: maximum 187.8 [± 3.4] beats min^{-1} during the jumping course) while heart rate of the riders was not affected by the level of experience of their horse (Figure 3[b]).

The HRV variable SDRR decreased significantly during riding in horses and their riders (both $P < 0.001$). In horses, the most pronounced decrease was found when the animals were mounted by the riders. The SDRR decreased further during trot but remained at that constant level during canter and the jumping course (Figure 4[a]). SDRR did not differ significantly between groups of horses and was neither affected by experience of the rider nor were interactions of time × experience of the horse or time × experience of the rider significant. Except for the trot, canter and jumping phase, SDRR was always higher in experienced compared to less-experienced riders ($P < 0.01$; Figure 4[b]) but was neither affected by experience of the equine partner nor were there any significant interactions. During the jumping course with a less-experienced horse, SDRR of less-experienced riders decreased to a minimum of 2.9 (± 0.2) ms (3.4 [± 0.5] ms with experienced horse) in contrast to the experienced riders with a minimum of 5.8 (± 1.3) ms (7.2 [± 2.0] ms with experienced horse).

Figure 3

Heart rate before and after a standardised jumping course in (a) experienced (■) and less-experienced horses (□) and (b) experienced (●) and less-experienced riders (○) with experienced (continuous lines) and less-experienced (dashed lines) partners of the other species. Shaded bar = riding time.

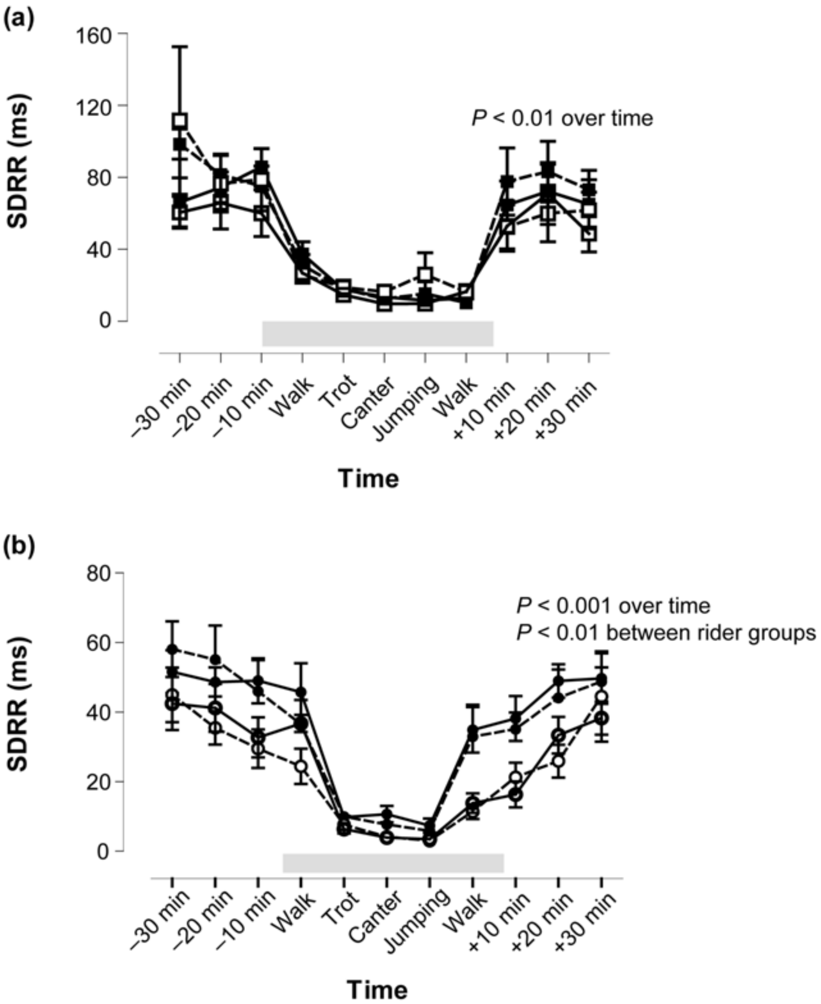


For RMSSD, a significant decrease during riding was found in horses and riders (both $P < 0.001$). RMSSD was higher in experienced horses ($P < 0.05$) and riders ($P < 0.001$) versus less-experienced horses and riders, respectively, and in the riders, significant interactions between time and group existed ($P < 0.05$; Figure 5). RMSSD reached a nadir during walk, trot, canter and jumping course in horses and during the trot, canter and jumping phase in riders.

Discussion

In this study, horses and riders responded to the challenges of a showjumping course with consistent increases in heart rate, decreases in heart-rate variability but a less consistent increase in salivary cortisol concentrations. In general, in less-experienced riders, cortisol concentrations and heart rate were higher and HRV variables SDRR and RMSSD lower than in experienced riders while comparable differences were either absent or much less pronounced between experienced and less-experienced horses. All horses and riders were well trained and within an age range where physical fitness for the task associated with the experiment has to be considered excellent. Although a partial influence of the differences in age between horses and riders cannot be totally excluded, major age effects are extremely unlikely. In the less-experienced riders, cortisol release in response to the equestrian tasks was affected by the experience of their equine partners with higher salivary cortisol concentrations in riders on a less-experienced versus an experienced horse. Thus, both their own experience and the level of experience of the equine partner, influence, to a certain degree, the response of riders to challenges in equestrian sports. Different from their riders, in horses at least as long as the required task does not exceed their abilities, increased experience is not associated with a reduced stress response. In addition, the stress response of the horses was not affected by the level of experience of their riders and, in particular, not increased when the horses were ridden by less-experienced riders. The equestrian tasks in the present study caused a stress response but it is unlikely that they were associated with any fear in the

Figure 4



HRV variable SDRR before and after a standardised jumping course in (a) experienced (■) and less-experienced horses (□) and (b) experienced (●) and less-experienced riders (○) with experienced (continuous lines) and less-experienced (dashed lines) partners of the other species. Shaded bar = riding time. Note different scales on y-axis.

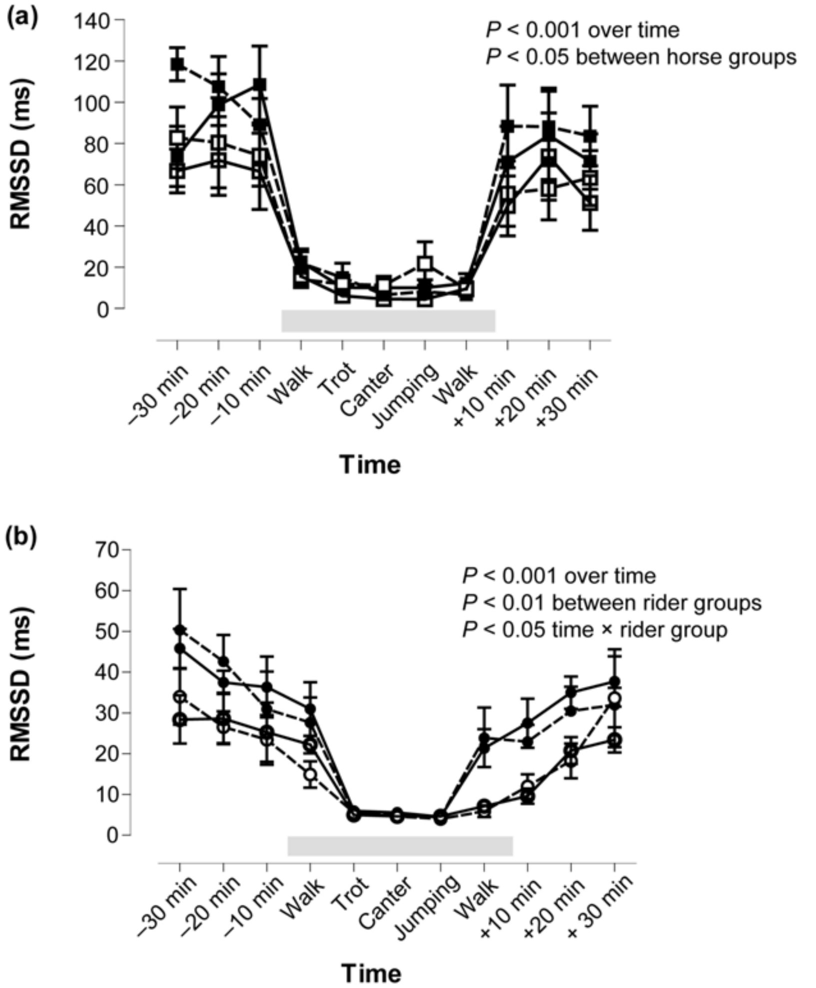
riders or their horses. In a preliminary study, fear in riders affected heart rate in their horses (Keeling *et al* 2009). We suggest that the response of horse-rider pairs to challenges in equestrian sports differs from situations that may initiate a sudden flight response in horses. The less-experienced riders in our study were in the first year of a systematic equestrian training. Although clearly differing from the experienced riders they were not totally inexperienced. A more pronounced physiological stress response in horses cannot be excluded if they were required to jump a course of obstacles with riders classified as true beginners.

In horses of both groups, an increase in salivary cortisol concentrations was found in response to riding and was not affected by experience of the rider. Cortisol concentrations were in the same order of magnitude as in horses lunged without a rider (Becker-Birck *et al* 2012a) or participating in equestrian competitions in showjumping and dressage (Becker-Birck *et al* 2012b) but remained below values measured in horses during transport (Schmidt *et al* 2010b,c) or young horses mounted for the first time by a rider (Schmidt *et al* 2010a). Although cortisol release mirrors only part of the physiological stress response, these results indicate that neither in experienced nor less-experienced horses is a jumping course of obstacles up to 90 cm in height a major stressor. A performance of classical dressage at advanced level elicited a markedly more pronounced stress response than the showjumping tasks of the current study (von Lewinksi *et al* 2013). We suggest that advanced-level dressage technically and physically is more demanding and potentially a more pronounced stressor than jumping the relatively small training obstacles in the current study. Increasing the height of the fences in the current study was not possible with the less-experienced horses and riders. Both might have been over-challenged and with horses potentially refusing at individual jumps, standardisation of the test and thus comparability between groups would have been lost.

In the horses' human partners, a clear increase in cortisol concentrations was seen when less-experienced riders rode a less-experienced horse. This combination was also expected to be associated with the most pronounced stress response. However, the initial hypothesis could be verified

Figure 5

HRV variable RMSSD before and after a standardised jumping course in (a) experienced (■) and less-experienced horses (□) and (b) experienced (●) and less-experienced riders (○) with experienced (continuous lines) and less-experienced (dashed lines) partners of the other species. Shaded bar = riding time. Note different scales on y-axis.



only for the riders but not for the horses. Results are in agreement with a slight but significant increase in salivary cortisol concentrations in riders during a dressage performance (von Lewinski *et al* 2013). Compared to ergometer studies in human athletes, where an exercise at 80% of maximal oxygen intake over 30 min caused a 170% increase in salivary cortisol concentrations (van Bruggen *et al* 2011), the equestrian tasks of the current study were no major stressor and only a medium-intensity exercise.

Heart rate in horses increased continuously from basal values through walk, trot and canter and reached highest values during the jumping course. However, heart-rate profiles were identical for experienced and less-experienced horses and not affected by the level of experience of the riders. The equestrian tasks in the current study remained well below the training level and skills of the experienced horses but the cardiac effort was the same in both groups of horses. In contrast, heart rate in less-experienced riders at all times before, during and after riding was higher than in the experienced riders. The peak mean heart rate of the experienced riders remained below the values reported previously in riders during showjumping whereas heart rate in the less-experienced riders in our study exceeded the previously reported values (Devienne & Guezennec 2000). Heart rate in both groups of riders was not affected by the level of experience in their horses. The similar increase in heart rate of horses of both groups indicates that the physical demand of the equestrian tasks was identical for all horse and rider pairs. The higher heart rate in less-experienced riders during but also before riding indicates an anticipatory excitation in humans. A higher heart rate in less-experienced versus experienced human athletes is not surprising and has also been reported in competitive archers (Clemente *et al* 2011). The different cardiac response in less-experienced versus experienced riders was, however, not reflected by similar changes in heart rate of their horses, indicating no interaction between the cardiac responses in riders and their horses. Increases in heart rate of the horses apparently were caused to a large extent by physical activity. However, the clear increase in heart rate during the walk phase which represented only minor physical activity indicates that emotional factors also contribute to changes in heart rate of ridden horses.

Both HRV variables, SDRR and RMSSD, decreased in horses and their riders in response to the equestrian tasks of the study but HRV profiles differed between horses and riders and also between experienced and less-experienced riders. In horses, SDRR and RMSSD decreased when the riders mounted and started to ride 'in walk'. Only a slight decrease in SDRR and no further decrease in RMSSD occurred at trot and both HRV variables remained at a constant low level through canter, jumping and the post-jumping walk phase. A decrease in heart-rate variability may indicate increased sympathetic activity and less parasympathetic (vagal) activity with the RMSSD more specific for vagal activity and indicative of a stress response (von Borell *et al* 2007). Thus, a certain stress response is initiated when the horse is mounted by the rider, while increasing equestrian demands during riding, at least in trained horses, apparently are not perceived as additional stressors. They lead to further changes in heart rate but not heart-rate variability. Changes in HRV thus did not parallel the changes in heart rate. While SDRR at no time was affected by experience of the horse or rider, RMSSD was higher before and after but not during riding in the experienced horses, indicating a higher vagal tone in experienced horses at rest. In riders, both HRV variables decreased only during trot, canter and jumping but not the walk phases of riding. While, in the horses, changes in HRV were seen directly after mounting of a rider, such a response in the riders did only begin with more pronounced physical activity. Both HRV variables were higher in experienced than in less-experienced riders before and after the phase of physical activity. Thus, the equestrian tasks themselves affected experienced and less-experienced riders in the same way, but before and after these physical efforts, the experienced riders appeared to be under less emotional stress. We have previously shown clear effects of the presence of spectators at a performance on the physiological stress response in experienced riders but not their horses (von Lewinski *et al* 2013). The present study extends these findings. Emotional factors such as anticipation of a difficult task or a certain pressure to perform well, initiate a stress response in riders. The subjective classification of the difficulties associated with equestrian tasks is obviously influenced by the experience of the rider. In horses, the level of experience — at least for the two levels investigated in this study — does not affect the physiological stress response.

Animal welfare implications

Being ridden evokes a physiological stress response in horses with an increase in cortisol release and a decrease in heart-rate variability. However, these changes are less pronounced than the response to many other physiological stressors to which horses are regularly exposed. Being ridden by less-experienced riders over a course of jumping obstacles does not increase the animals' stress response compared to horses ridden by highly experienced riders.

Conclusion

The equestrian challenge of jumping a standardised course differentially affected cortisol release, heart rate and HRV in experienced versus less-experienced riders while no marked differences were found between experienced and less-experienced horses. The emotional and physical stress response of riders in equestrian sports appears to be much more affected by external factors than the same response in their horses. As long as horses are not over-challenged or frightened they apparently perceive the challenges of equestrian sports more uniformly than their riders.

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