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Cortisol release, heart rate and heart rate variability in the horse and its rider: Different responses to training and performance

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ABSTRACT

Although some information exists on the stress response of horses in equestrian sports, the horse-rider team is much less well understood. In this study, salivary cortisol concentrations, heart rate (HR) and heart rate variability (HRV), SDRR (standard deviation of beat-to-beat interval) and RMSSD (root mean square of successive beat-to-beat intervals) were analysed in horses and their riders (n = 6 each) at a public performance and an identical rehearsal that was not open to the public.

Cortisol concentrations increased in both horses and riders ($P < 0.001$) but did not differ between performance and rehearsal. HR in horses and riders increased during the rehearsal and the public performance ($P < 0.001$) but the increase in HR was more pronounced ($P < 0.01$) in riders than in their horses during the public performance (from 91 ± 10 to 150 ± 15 beats/min) compared to the rehearsal (from 94 ± 10 to 118 ± 12 beats/min). The SDRR decreased significantly during the equestrian tasks in riders ($P < 0.001$), but not in their horses. The RMSSD decreased in horses and riders ($P < 0.001$) during rehearsal and performance, indicating a decrease in parasympathetic tone. The decrease in RMSSD in the riders was more pronounced ($P < 0.05$) during the performance (from 32.6 ± 6.6 to 3.8 ± 0.3 ms) than during the rehearsal (from 27.5 ± 4.2 to 6.6 ± 0.6 ms). The study has shown that the presence of spectators caused more pronounced changes in cardiac activity in the riders than it did in their horses.

Introduction

The stress response of horses to challenges during equestrian sports has prompted increasing research interest. Stressful stimuli initiate hypothalamo–pituitary–adrenocortical, adrenomedullary and sympathetic nervous system responses. During short-term stress, increased cortisol release may improve fitness by energy mobilisation (Reynaert et al., 1976) and changes in behaviour (Korte, 2001). Because cortisol rapidly diffuses into saliva, salivary cortisol concentrations reliably mirror changes in cortisol concentrations in blood plasma (Peeters et al., 2011).

The most immediate stress response is an increase in adrenomedullary and sympathetic nervous activity, leading to a release of epinephrine and rise in heart rate (HR). In addition, heart rate variability (HRV; short-term fluctuations in HR) is an indicator for the response of the autonomic nervous system to stress and reflects the oscillatory antagonistic influence of the sympathetic and parasympathetic branch of the autonomous nervous system on the sinus node of the heart (von Borell et al., 2007).

Equestrian sports are unique in the sense that they demand the cooperative effort of two non-related species, horses and humans. Positive interaction of the horse and its rider when coping with the emotional and physical challenges of equestrian tasks is a prerequisite for success in sportive competitions. Whereas information exists on the cardiovascular and endocrine response of horses to equestrian training (Dybdal et al., 1980; Cayado et al., 2006; Schmidt et al., 2010a; Becker-Birck et al., in press-a, in press-b), less is known about the response of the rider (Westerling, 1983; Trowbridge et al., 1995; Devienne and Guezennec, 2000). The combined response of the horse-rider team is not well understood.

In a preliminary study, it was found that anticipating a horse's response to a novel object was associated with increased heart rate in the person riding a horse as well as in the animal itself (Keeling et al., 2009). The response of riders to equestrian challenges is not only determined by the physical demands themselves but also by the state of anxiety that may differ between training and competition or performances. Horses respond with an increase in heart rate

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to novel stimuli (Christensen et al., 2006) or situations such as transport (Schmidt et al., 2010b,c), or when mounted for the first time by a rider (Schmidt et al., 2010a). This response decreases with repeated exposure to the same challenge (Schmidt et al., 2010a,b,c). To the best of our knowledge there have been no reports to date examining the extent to which horses perceive the presence of spectators as a challenge at equestrian performances.

In this study, we have analysed HR, HRV and cortisol release as physiological stress parameters in horses and their riders during a public equestrian performance and during a rehearsal that differed from the public performance only by the absence of spectators. We hypothesised that the presence of spectators and the performance atmosphere are perceived by the horses and their riders as a stressful challenge and that the responses of both are closely correlated.

Materials and methods

Horses and riders

For the study, sport horses ($n = 6$) of the French National School for Equitation (ENE), Saumur, were available. The mean age of the horses was 9.7 ± 2.3 years (±SD, 8–11 years) and all were geldings and of the French Sport Horse breed. The animals were kept in individual boxes on straw and fed concentrates three times daily with hay twice daily. Water was available at all times. Horses were exercised on a near-daily basis, (i.e. 5–6 times per week) and were trained for dressage at advanced level including the schools (airs) above the ground.

All riders participating in the study ($n = 6$) were male and members of the classical dressage team of the ENE (Cadre noir de Saumur) and were qualified as professional riders at the highest level of equestrian sports in France. The mean age of the riders was 38.3 ± 4.6 years (±SD, 30–42 years).

All horses were familiar with their rider and vice versa and the pair had been training together for at least 6 months before the study. Both the horses and riders were also well acquainted with the indoor riding arena used for the performance and rehearsal, the warm up arena, the equestrian tasks required, and the presence of spectators.

Experimental design

Horses and riders were studied during a riding performance of the schools (airs) above the ground at the ENE and during a rehearsal for such performances. The airs above the ground or school jumps are a series of higher-level classical dressage movements in which the horse leaves the ground.[1] In this study, they included the *courbette*, the *croupade* and the *capriole*. Horses with the riders mounted were warmed up for between 30 and 40 min before the performance or rehearsal but the warm-up period was excluded from our analysis.

The performances and rehearsals followed an exact and identical choreography and were ridden simultaneously by a group of eight horse-rider pairs. Each performance lasted 7 min and consisted of being ridden in canter and included the airs above the ground (18 jumps). One rider refused to participate in the study and one horse was changed between the rehearsal and performance. Only complete horse-rider pairs were included and thus the number of horses and riders analysed was $n = 6$ each per performance and rehearsal, respectively.

A total of 2–4 horses and riders per session were included in the study and so two performances and rehearsals each were used. The time between experiments was 2 days with four horses and four riders tested in the rehearsal first and the performance thereafter, and the other two horses and riders in the opposite order.

The performances and rehearsals were ridden in the same indoor riding arena and at the same time of the day (including warm up between 10:30 and 12:00 h) and differed only by the presence and absence of spectators (1200 people).

Cortisol analysis

Saliva for determination of basal cortisol concentrations was taken from horses at 30 and 15 min and from riders at 30 min before the riders mounted their horses. Further samples from both horses and riders were taken immediately after each performance and rehearsal, respectively, at Time 0 and at 15, 30 and 60 min thereafter.

In the horses, saliva was collected as described by Schmidt et al. (2010c) with cotton rolls (Salivette, Sarstedt) placed loosely onto the tongue of the horse for 1 min with the help of a surgical arterial clamp until the swab was well soaked. Riders placed the Salivette into their own mouth and gently chewed to stimulate salivation for 1 min. The Salivettes were then centrifuged for 10 min at 1000 *g* and saliva was aspirated and frozen at −20 °C until cortisol analysis.

[1] See: www.cadrenoir.co.uk/the-airs-above-the-ground.

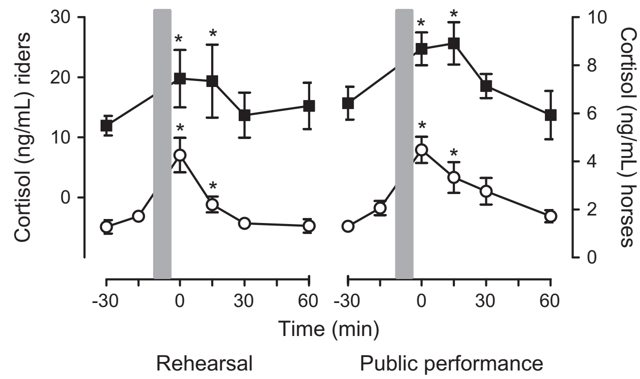

Fig. 1. Cortisol concentration in saliva of horses (○; $n = 6$) and riders (■; $n = 6$) before and after a non-public rehearsal and a public performance of classical dressage. Shaded bars indicate time of rehearsal and performance, respectively. *Values differ significantly from baseline with at least $P < 0.05$. Data are means ± SEM.

Concentrations of cortisol were determined by enzyme immunoassay without extraction (Palme and Möstl, 1997; Schmidt et al., 2009). Since the antiserum cross-reacts with cortisone and some cortisone metabolites, values were interpreted as cortisol immunoreactivity. The intra-assay coefficient of variation was 5.0%, the inter-assay variation 6.7% and the minimal detectable concentration 0.3 pg/well.

Heart rate and heart rate variability

The cardiac beat-to-beat (RR) interval was recorded in horses and riders with a mobile recording system (S810i, Polar) set to RR interval. Recordings in horses were performed as described elsewhere (Schmidt et al., 2010a,c). Recordings in riders were made following the manufacturer's recommendations with two electrodes fixed to the chest with an electrode transmitter belt and a recording watch placed on the wrist. Recordings were made for 1 h directly before riding, continuously during riding and for 1 h thereafter in the horses, and for 30 min directly before riding and continuously during riding in the riders. Recordings before riding were made with the riders standing.

From the RR interval, HR and HRV variables, the standard deviation of RR interval (SDRR) and root mean square of successive RR differences (RMSSD) were calculated. HRV was analysed using Kubios HRV software.[2] To remove trend components, data were de-trended and an artefact correction was made as described elsewhere (Tarvainen et al., 2002; Schmidt et al., 2010a,c).

For comparisons of HR and HRV over time, the 7-min performance and rehearsal, respectively, were each divided into 1 min intervals. Baseline values were determined in horses and riders for 1 min intervals starting 10 min and 5 min before the riders mounted. In addition, 1 min interval recordings beginning 5, 10 and 15 min after riding were analysed in the horses, but post-riding recordings were not possible in the riders.

Statistical analysis

Statistical analysis was done with the SPSS statistics package (version 17.0, SPSS). All data were normally distributed (Kolmogorov–Smirnov-test). Changes over time were analysed for horses and riders by ANOVA using a general linear model for repeated measures with type of equestrian activity (performance or rehearsal) as between subject factors and for horses and riders combined with horse-rider pairs as fixed effect. All data given are mean ± SEM. A *P*-value below 0.05 was considered significant.

Results

Cortisol

In response to both the public performance and an identical rehearsal of the airs above the ground, cortisol concentrations increased significantly in horses ($P < 0.001$) and their riders ($P < 0.01$) and were significantly higher than baseline values immediately (Time 0) and 15 min after the equestrian tasks (Fig. 1).

[2] Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland.

Cortisol release did not differ significantly in either horses or riders between rehearsal and performance but when cortisol release was analysed between horse-rider pairs, irrespective of rehearsal and performance, the interactions of time × horse-rider pairs were statistically significant ($P < 0.05$).

Heart rate and heart rate variability

HR in both horses and riders increased during riding, both in the rehearsal and the public performance ($P < 0.001$) and remained significantly elevated vs. baseline throughout the riding time. In horses, this increase in HR did not differ between non-public rehearsal and public performance (rehearsal: from 35 ± 6 in the stable to 97 ± 17 beats/min during riding; performance: from 43 ± 13 to 103 ± 13 beats/min, respectively; Fig. 2). In contrast, in the riders, the increase in HR was more pronounced during the public performance (from 91 ± 10 to 150 ± 15 beats/min) than during the non-public rehearsal (from 94 ± 10 to 118 ± 12 beats/min; $P < 0.01$; Fig. 2) with significant interactions of time × type of activity ($P < 0.001$). For HR, neither significant differences between horse-rider pairs nor significant interactions of time × horse-rider pairs existed.

With regard to HRV, in horses SDRR did not change significantly during equestrian activities and did not differ between types of activity. In riders, SDRR decreased during riding for the complete duration of the equestrian tasks ($P < 0.001$) with a more pronounced decrease during a performance vs. rehearsal (Fig. 3a). During the performance, SDRR in riders decreased from 45.2 ± 8.7 to a minimum of 4.5 ± 0.9 ms while respective values for the rehearsal session were 44.8 ± 5.1 and 12.3 ± 1.7 ms. The RMSSD decreased significantly during equestrian activities in both horses and their riders ($P < 0.001$). There was no difference between rehearsal and performance in horses but, in riders, the decrease in RMSSD was significantly more pronounced during a performance vs. rehearsal ($P < 0.05$; Fig. 3b) and significant interactions of time × type of activity were found ($P < 0.05$). Significant differences between horse-rider pairs or significant interactions of time × horse-rider pairs were not found for any of the HRV variables.

Discussion

Both a public performance and an identical non-public rehearsal of classical dressage caused an increase in cortisol release and HR and a decrease in HRV in horses as well as their riders. The increase in HR and decrease in HRV in the riders, but not their horses, was more pronounced during the public performance than during the non-public rehearsal of the same equestrian tasks. Thus the physiological response of the riders, but not their horses, differed between a public performance and a non-public rehearsal.

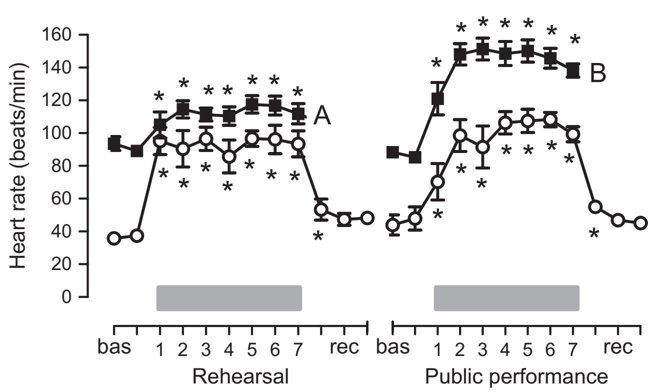

Fig. 2. Heart rate in horses (○; $n = 6$) and riders (■; $n = 6$) recorded for 1 min intervals at 10 and 5 min before (bas) and during a 7 min rehearsal and public performance of classical dressage (minutes 1–7). Additional recordings were made in horses during the recovery phase (rec) starting at 5, 10 and 15 min after dismounting. Shaded bars parallel to the *X*-axis indicate the time of rehearsal and performance, respectively. *Values differ significantly from baseline with at least $P < 0.05$, A and B: significant differences between rehearsal and performance in riders ($P < 0.01$). Data are means ± SEM.

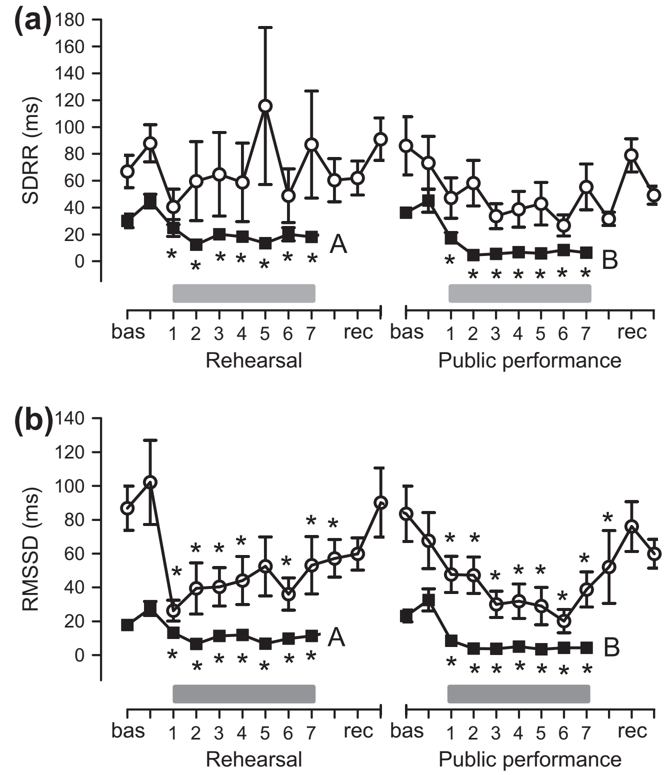

Fig. 3. HRV variables (a) SDRR and (b) RMSSD in horses (○; $n = 6$) and riders (■; $n = 6$) recorded at 1-min intervals at 10 and 5 min before (bas) and during a 7 min rehearsal and public performance of classical dressage (minutes 1–7). Additional recordings were made in horses during the recovery phase (rec) starting at 5, 10 and 15 min after dismounting of the rider. Shaded bars parallel to the *X*-axis indicate time of rehearsal and performance, respectively. *: values differ significantly from baseline with at least $P < 0.05$, A and B: significant differences between rehearsal and performance in riders ($P < 0.05$). Data are means ± SEM.

The equestrian tasks were ridden in a group of eight horse-rider pairs at the same time and following exact commands. This group performance thus provided a standardised test more difficult to obtain in horse and riders participating individually in equestrian competitions. The public performance and non-public rehearsal thus did not differ with regard to the physical efforts, which is supported by the identical cardiac response of the horses. The presence of spectators caused a different physiological response in riders than the same equestrian tasks ridden without spectators present.

While increases in HR are mainly caused by physical activity, decreases in HRV also indicate a stress response. During the public performance, decrease in the HRV variables SDRR and RMSSD in riders were more pronounced than during a similar rehearsal session. A decrease in SDRR indicates increased sympathetic and decreased parasympathetic activity, while RMSSD is more specific for parasympathetic activity (von Borell et al., 2007). The presence of spectators may therefore cause a more pronounced sympathetic and/or decreased parasympathetic activity in riders. In contrast, spectators did not have any such effect in the horses.

During the presentation, but not the performance, it is possible that the riders might have been influenced by the expectations of the spectators, increased demands of their own superiors and trainers, or indeed an expectation of the riders themselves that their horses might be more difficult in a performance. All of these factors may have been perceived as potential psychological stressor by the riders. All riders in the study were qualified to the highest level in equestrian sports and an even more pronounced response to performances or competitions might occur in less experienced riders.

Although cortisol release in riders and horses did not differ between public performance and non-public rehearsal, in Olympic weightlifters (i.e. human athletes potentially under more emotional pressure than in our study), the actual competitions produced greater salivary cortisol responses than simulated competitions (Crewther et al., 2011). Also in equestrian sports, competitions may put more pressure on riders than a performance. However, in competing horses (Becker-Birck et al., in press-a), we did not find any significantly different stress response than we found in horses during a rehearsal and a public performance in the current study. Cortisol concentrations in our horses were in the same range as concentrations determined using the same analytical techniques in situations considered stressful for horses, namely, during road transport (Schmidt et al., 2010b,c), or in foals at weaning (Erber et al., 2012), but were higher than were found during moderate exercise in horses lunged without a rider (Becker-Birck et al., in press-b).

For cortisol, the current study revealed significant horse-rider interactions. Although all horses and riders were highly trained, this may indicate that a more seasoned performer, whether horse or rider, might be less stressed and thus might help calm their respective partner, so altering cortisol release.

During riding, HR increased and the HRV variable RMSSD decreased in the horses, but this response did not differ between the public performance and non-public rehearsal. Spectators appeared to have no effect on cardiac regulation in the horses and the more pronounced cardiac response of the riders was not transferred to the horses. Our initial assumption that a stress response of the rider directly affects his horse could not therefore be verified. The precise demands of equestrian dressage in well-trained horses and their riders caused a certain stress response but it is unlikely that these were associated with any fear in the animals. In addition, the highly experienced riders in our study were apparently able to control the interaction with their horses to a high degree. We suggest that our results can be largely generalised to tasks for which horses can be trained in equestrian sports and less to initiating a sudden flight response.

HR in the horses during the performance and rehearsal reached approximately 100 beats/min, which is similar to horses in equestrian competitions (Becker-Birck et al., in press-a) but less than in young horses mounted for the first time by a rider (Schmidt et al., 2010a). HR was not higher than in other horses performing less demanding equestrian tasks which may be due to a high degree of physical fitness of the horses in our study but might also indicate a less pronounced stress response. As in their horses, peak HR in the riders also remained considerably below values for riders during a show jumping course and resembled values found in other riders during a canter without additional efforts (Devienne and Guezennec, 2000). Basal HRVs in the riders were taken before the riders mounted their horses but cannot be considered as resting values because they were recorded with the riders standing and preparing themselves for riding.

Conclusions

The presence of spectators caused more pronounced increases in HR and decreases in HRV in experienced riders than the same equestrian tasks ridden without spectators present. In contrast, the presence of spectators had no additional effects on HR and HRV in experienced horses. Cortisol release did not differ in horses or riders between the same equestrian tasks during a rehearsal and a public performance. Horse and riders therefore were seen to respond differentially to the challenges associated with equestrian sports and a potential stress response of experienced riders is not transferred to their horses.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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