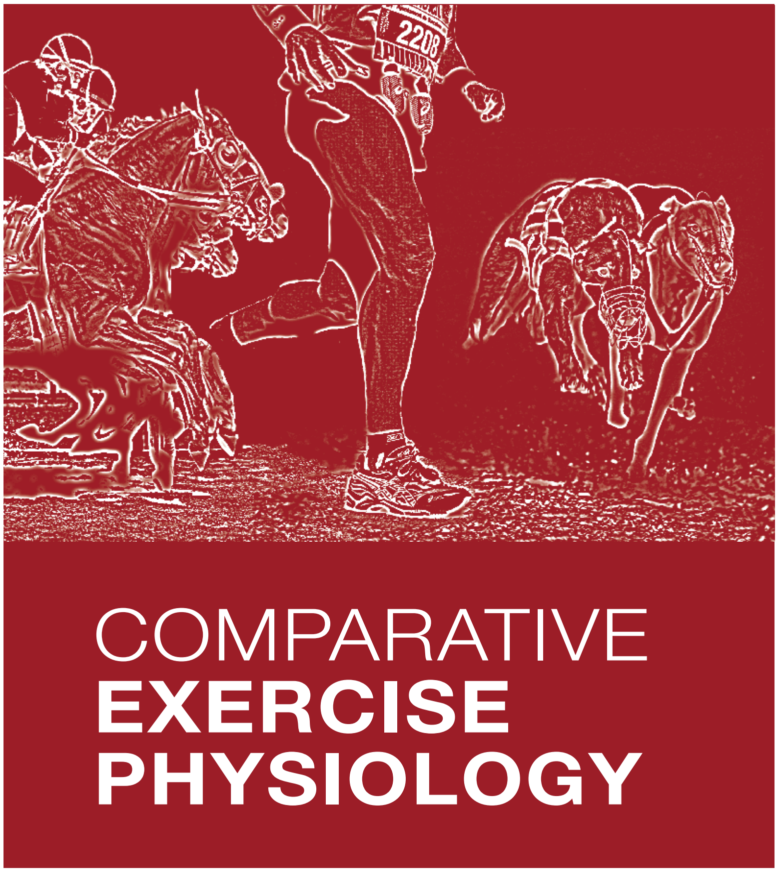
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Physiological stress responses and horse rider interactions in horses ridden by male and female riders

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RESEARCH ARTICLE

Abstract

Traditionally, horse riding has been restricted to men but today equestrian sports are dominated by women. We hypothesised that men and women differ with regard to riding and the response they evoke in their horse. Cortisol and heart rate variability (HRV) were studied in male (n=8) and female riders (n=8) and in horses (n=8) ridden by men and women over a jumping course. Saliva for cortisol analysis was collected, cardiac beat to beat (RR) intervals were recorded and heart rate and HRV variables SDRR (standard deviation of RR interval) and RMSSD (root mean square of successive RR differences) calculated. In another experiment, saddle pressure was compared between male and female riders (n=5 each). Cortisol did not differ between male and female riders and increased in horses (P<0.001) irrespective of the sex of the rider. Heart rate in riders increased from walk to jumping (P<0.001) while HRV decreased (P<0.001) to the same extent in men and women. In horses, heart rate increased (P<0.001) and SDRR and RMSSD decreased during walk and remained low at trot and canter (P<0.001) irrespective of the riders' sex. In trot (P<0.05) and canter (P<0.01) saddle pressure was slightly lower in female versus male riders. This is due to weight differences and not to a different seat. In conclusion, no fundamental differences existed in the physical effort, stress response and seat between male and female riders and in the response of horses to men and women.

Keywords: equitation, gender, cortisol, heart rate

1. Introduction

The stress response of horses and their riders to challenges in equestrian sports recently has been analysed. With regard to the riders, these studies either focused on male riders only or did not take the sex of the human athletes into account (Ille *et al.*, 2013; Von Lewinski *et al.*, 2013). Traditionally, horse riding has been largely, although not exclusively, restricted to the male half of the population. Thus, in Europe and North America the theories of horse riding and equestrian sports from the antique (Xenophon, approx. 350 B.C.) through equestrian arts in the renaissance (e.g. de la Guérinière, 1733) to the regulations for riding in the military of the 19th and 20th century (e.g. Blacque Belair, 1919; German Army, 1937) envisaged only male riders. Today equestrian sports are dominated by female human athletes. For example, in Germany 76% of all riders registered with the national equestrian federation are women (German Equestrian Federation, 2013) and similar numbers can be assumed for other industrial countries. Thus, a female-dominated sport is based on a theoretical background developed throughout history for males. It is often assumed that with regard to horse riding male and female athletes do not differ. Equestrian competitions are the only sport where men and women compete against each other from beginners´ level up to the Olympic Games. Although the hypothalamo-pituitary-adrenal responses to physical exercise appear not to differ between men and women, adult men respond to psychological stress with a more pronounced cortisol release than women (Friedmann and Kindermann, 1989; Kirschbaum *et al.*, 1992; Kudelka and Kirschbaum, 2005). Such sex differences have also been demonstrated in animals, but in animals glucocorticoid concentrations were usually higher in females than in males (reviewed by Kudelka and Kirschbaum, 2005). Therefore, in equestrian sports, male and female riders may interact differentially with their equine partners. Differences between male and female riders, if present, must be taken into account when planning training programs and equestrian theories developed for male riders may need to be adapted for todays´ female riders. In addition, detailed knowledge about sex-related differences in exercise and stress physiology is limited not only for equestrian disciplines but also for many other sports.

This study was divided into two experiments. In the first experiment, we have compared the physiological stress parameters cortisol and heart rate variability (HRV) in male and female riders exposed to the challenges of jumping a course of obstacles as well as in the horses ridden either by a male or a female rider. Stimuli perceived as stressful initiate a hypothalamo-pituitary-adrenocortical and an adrenomedullary and sympathetic nervous system response. During short-term stress, cortisol release increases. Non-protein-bound cortisol rapidly diffuses into saliva and salivary cortisol concentrations mirror changes of free cortisol in blood plasma (Peeters *et al.*, 2011). Acute stress as well as physical demands also elicit an epinephrine release and subsequent increase in heart rate. In exercising athletes, heart rate is mainly influenced by physical effort but also by emotional factors. HRV, i.e. short-term fluctuations in heart rate, reflects the oscillatory antagonistic influence of the sympathetic and parasympathetic branch of the autonomous nervous system on the sinus node of the heart, with a decrease in HRV indicating a stress response (Von Borell *et al.*, 2007).

In the second study, the pressure exerted on the saddle and thus indirectly on the horse´s back was determined and compared between male and female riders. The pressure pattern is influenced by various factors such as equestrian discipline, riding technique, training programme, anatomy of the individual horse, gait, velocity and saddle type (reviewed by Greve and Dyson, 2013). The pressure pattern exerted by the saddle on the back of the horse is strongly affected by the seat of the rider (Peham *et al.*, 2010). The seat differs between experienced and inexperienced riders with the trunk of less experienced riders tilted forward and experienced riders maintaining a position close to the vertical (Schils *et al.*, 1993). Experienced riders maintain a better synchronisation with their horse (Clayton *et al.*, 2011; Peham *et al.*, 2001) and may thus be able to apply their aids more efficiently than less experienced riders. To what extent male and female riders differ with regard to their seat in the saddle to the best of our knowledge has not been investigated so far.

We hypothesised that jumping a course of obstacles induces a more pronounced stress response in male than in female riders, while the response of the horse is not affected by the sex of its rider. In addition, men have a more backward leaning seat and exert more force on the horse through their seat in the saddle than women.

2. Materials and methods

Physiological stress parameters (experiment 1)

Horses and riders

For this study, 8 male horses (7 geldings and one stallion) of the Brandenburg State Stud at Neustadt (Dosse), Germany were available. All horses were assigned to the stud´s riding school and were exercised nearly every day, i.e. 5 to 6 days per week. The horses were used to varying riders of different sex and equestrian experience. Mean age of the horses was 11.0±3.2 years. Horses were kept in individual loose boxes on wood chippings, had access to a paddock for several hours per day and were fed concentrates and hay twice daily. Water was available *at libitum*.

The riders participating in the study were apprentices or riding students (n=16) from the Brandenburg State Stud. For this study, they were divided in two groups (n=8 each) by their sex and ranked by equestrian experience by their trainer. Two riders of nearly equal experience from both groups were then assigned to the same horse. Mean age was 21.5±1.4 and 19.8±2.2 years for female and male riders, respectively. All riders were used to exercise different horses nearly every day.

Experimental design

All horses and riders had to manage a standardised jumping course of moderate difficulty (Figure 1). The tests were performed in the same indoor riding arena following the same procedure for all participants. Each horse took part twice, one time with a male and one time with a female rider. The order of male and female riders per horse was arranged in a Latin square design and the interval between the two tests in the horse was always one day.

Before saddling their horse, riders had to rest in the horse stable building for at least 30 min without performing any physical activity. After mounting the horse in front of the stable and riding in walk a distance of 300 m to the indoor arena, 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. For all participating horse rider pairs this was followed by the jumping course, that consisted of 8 obstacles. The jumping course was followed by 5 min cooling down in the arena and riding

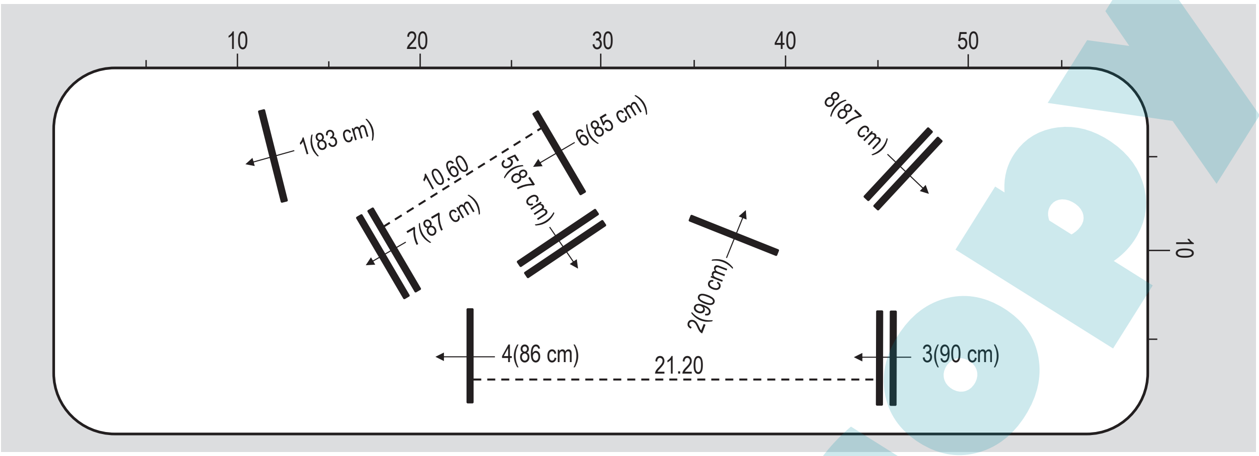

Figure 1. Show jumping course used for the study with size of the arena, type and height of obstacles and distances between obstacles on a straight line indicated.

back to the stables were the riders dismounted. Saliva for cortisol analysis was collected repeatedly before and after the jumping course and cardiac beat to beat (RR) intervals were recorded continuously before, during and after the equestrian tasks from all horses and riders. Riders and horses had to rest until 60 min after the equestrian tasks of the study.

Cortisol analysis

For determination of cortisol concentration, saliva was taken at 60, 30 and 15 min before start of the jumping course and at 0, 15, 30 and 60 min thereafter. Saliva collection in horses was performed as described by Schmidt *et al.* (2010c) and Becker-Birck *et al.* (2012) by placing a cotton roll (Salivette; Sarstedt, Nümbrecht-Rommelsdorf, Germany) grasped with a surgical clamp into the mouth of the horse for 1 min until the roll was well moistened. The riders had to chew gently to stimulate salivation, while keeping the salivette in their mouth for approximately 1 min as described (Becker-Birck *et al.*, 2012; Ille *et al.*, 2013). After saliva collection, the salivettes were centrifuged for 10 min at 1000×*g*, saliva was aspirated and at least 1 ml was frozen at -20 °C in polypropylene tubes until cortisol analysis. For determination of cortisol in saliva a direct enzyme immunoassay without extraction (Palme and Möstl, 1997) validated for equine saliva (Schmidt *et al.*, 2010c) was used. Because the antiserum cross-reacted with cortisone and some cortisone metabolites, cortisol concentrations have to be interpreted as cortisol immunoreactivity. The intra-assay coefficient of variation was 5.0%, the inter-assay variation was 6.7% and the minimal detectable concentration was 0.3 pg/well.

Heart rate and heart rate variability

Cardiac beat-to-beat intervals in horses and riders were analysed with a mobile heart rate monitoring system (S810i; Polar, Kempele, Finland) as described (Becker-Birck *et al.*, 2012; Ille *et al.*, 2013; Schmidt *et al.*, 2010a,c). Recording started 60 min before the jumping course and lasted until 60 min thereafter. To compare heart rate and HRV between groups, 1 min intervals were selected starting at 30 and 15 min before the jumping course, during the warm-up walk, trot and canter, the jumping course and immediately and 15 and 30 min after finishing the course.

From the recorded RR intervals, heart rate and HRV time domain variables SDRR (standard deviation of RR interval) and RMSSD (root mean square of successive RR differences) were calculated with the Kubios HRV software (Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland). To remove trend components, data were detrended and, in addition, an artefact correction was made as described (Schmidt *et al.*, 2010a,c) following established procedures (Tarvainen *et al.*, 2002).

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 by ANOVA using a general linear model for repeated measures with sex of riders as between subject factor. A P-value <0.05 was considered significant.

Saddle pressure (experiment 2)

Horse and riders

In the second study, one 4-year-old Warmblood sport horse gelding of the Brandenburg State Stud was used in all trials to avoid variations between different horses. Weight of the horse was 600 kg and height at withers 167 cm. The horse was without clinical signs of back pain and lameness, kept in an individual loose box on wood chippings and was fed concentrates and hay twice daily. Water was available *at libitum*. The horse was used to be ridden by different male and female riders and was familiar with the indoor riding arena used for the study.

The participating riders were apprentices (n=10) of the Brandenburg State Stud. They were divided by their sex into two groups (n=5 each). Age and body weight of female riders was 22.4±0.6 years and 72±7 kg, respectively, and age and body weight of male riders was 21.0±2.0 years and 77±9 kg, respectively.

Experimental design

The pressure exerted by the male and female riders via the saddle onto the back of the horse was determined with a pressure measuring pad (T&T Medilogic Medizintechnik, Schönefeld, Germany) placed under the saddle. The anatomically formed saddle pad consisted of 446 sensors (680×710 mm) allowing analysis of localised pressure peaks under the saddle with a measure frequency of 60 Hz. All riders used the same jumping saddle (Kentaur Titan II; Kentaur Saddlery, Prostějov, Czech Republic). Weight of the saddle was 8.3 kg including saddle girth and stirrups.

Standardised measurements (Meschan *et al.*, 2007) were made with horses in walk, trot (with the rider sitting continuously) and canter. Measurements were repeated on the left and right hand (the horse moving clockwise and counter-clockwise in a rectangular riding arena) on a straight line. Data were collected from at least 7 motion cycles per gait. A video was made continuously from the beginning of the task to document any deviation from a regular forward movement of the horse rider pair. However, no such deviations occurred during riding and all recordings were valid. The data from the pressure-measuring pad on the horse back were transmitted wireless to a computer. Before measuring, the pad was calibrated to zero after placing the saddle on the horse and tightening the girth. Data evaluation was performed with the Medilogic software by comparing intervals of 5 s per exercise. Average pressure for the 5 s intervals was used for further data processing. For analysis, the measuring pad was divided into three equal size segments (cranial, middle and caudal) on each side. For each sector the average pressure onto the horse back during walk, trot and canter was analysed. Data from the left and corresponding right side segment were then combined and averaged. In addition, data from the right and left hand recordings were averaged before further statistical analysis.

Statistical analysis

Statistical analysis was made with the SPSS statistics package. Because not all data were normally distributed they were log-transformed. Average saddle pressure was then analysed separately for each gait (walk, trot, canter) by ANOVA using a general linear model for repeated measures with saddle segment (cranial, middle and caudal) as within subject factor and sex of rider (male, female) as between subject factor. A P-value <0.05 was considered significant.

3. Results

Cortisol in riders and horses

Cortisol concentrations in saliva of riders at all times were higher than the respective values in their horses. Salivary cortisol in riders did not change significantly before, during and after jumping a course of obstacles and did not differ between male and female riders (e.g. 15 min before jumping 13.8±2.1 and 11.8±1.8 ng/ml, 15 min after jumping 13.9±4.2 and 11.7±2.7 ng/ml in male and female riders, respectively; Figure 2A). In contrast, cortisol in saliva of horses increased significantly (P<0.001) in conjunction with the equestrian tasks of the study, but was not affected by the sex of the rider. Cortisol concentrations in saliva of horses were 0.8±0.1 ng 15 min before and 1.8±0.4 ng/ml 15 min after jumping when ridden by a male rider. When ridden by a female rider, corresponding values were 0.9±0.1 and 1.6±0.3 ng/ml, respectively (Figure 2B).

Heart rate and heart rate variability in riders and horses

Heart rate in riders increased continuously from rest (male riders 102±4 bpm, female riders 107±2 bpm) to walk, trot and canter, reaching a maximum during the jumping course (male riders 176±5 bpm, female riders 172±4 bpm) and declined to baseline values within 15 min thereafter (P<0.001 over time, Figure 3A). Both HRV variables, SDRR and RMSSD, decreased during the trot, canter and jumping phase in riders and increased within 30 min thereafter (P<0.001 over time; e.g. SDRR from 28.2±5.3 ms at 15 min before riding to 3.6±0.3 ms at jumping in male and from 26.2±10.1 to 6.6±1.9 ms in female riders; Figure 3B,C). Changes in heart rate, SDRR and RMSSD did not differ at any time between male and female riders.

In horses, as in their riders heart rate increased continuously from rest (39±1 and 39±2 bpm with male and female riders, respectively) to walk, trot, canter and the jumping phase (152±4 and 152±6 bpm with male and female riders,

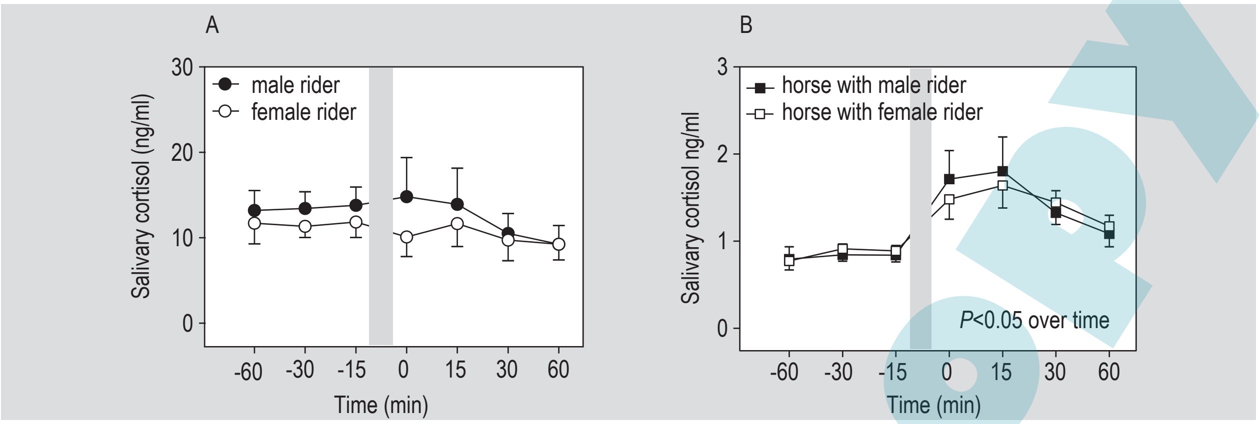

Figure 2. Salivary cortisol concentration before and after jumping a course of obstacles in (A) male and female riders and (B) horses ridden by either a male or a female rider. Grey bars indicate time for the warm-up period and jumping of obstacles (note different scales on y-axis).

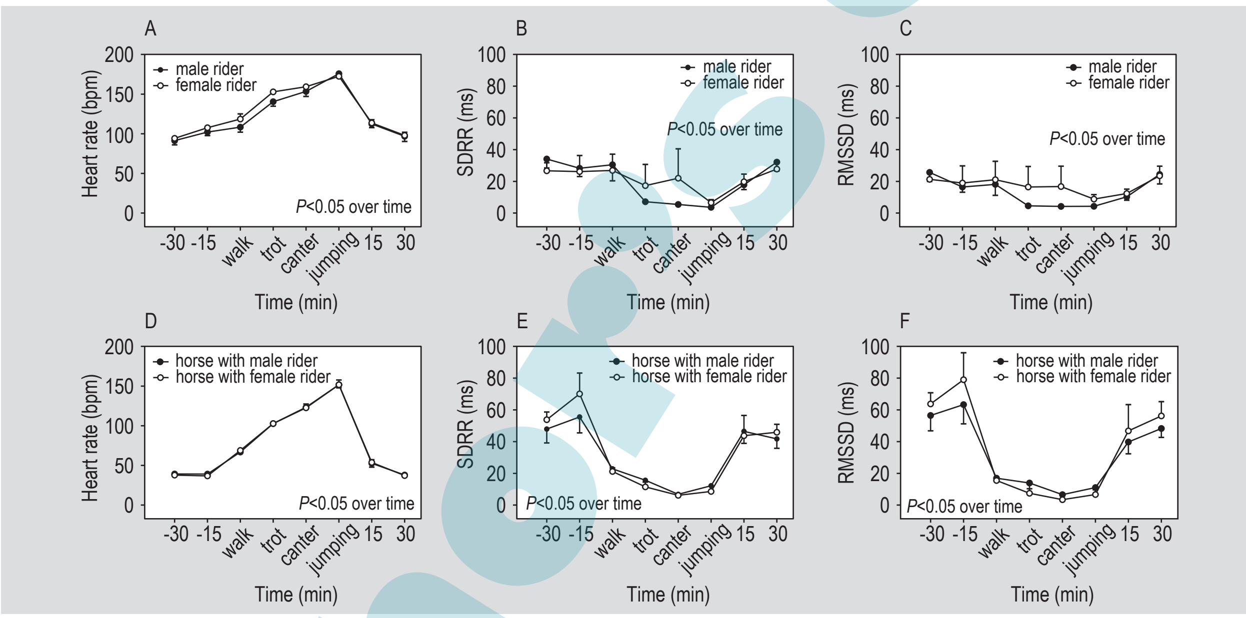

Figure 3. (A,D) Heart rate and HRV variables (B,E) SDRR and (C,F) RMSSD at rest, during a warm-up phase (walk, trot and canter), during jumping a course of obstacles and at 15 and 30 min thereafter in (A-C) male and female riders and (D-F) horses ridden by either a male or a female rider.

respectively) and returned to baseline values within 15 min after the jumping course (Figure 3D; *P*<0.001). HRV parameters SDRR and RMSSD decreased during walk and remained low during trot, canter and jumping and increased thereafter (*P*<0.001; e.g. SDRR from 55.6±10.1 ms at 15 min before riding to 6.8±1.4 ms at jumping with a male rider and from 70.1±13.2 to 6.2±1.1 ms with a female rider; Figure 3E,F). The sex of its rider did not affect heart rate, SDRR and RMSSD of the horse during the equestrian tasks.

Saddle pressure

Average saddle pressure determined with a measuring pad differed significantly between the cranial, middle and caudal segment of the pad in all three gaits. In both male and female riders, average pressure was highest in the middle and lowest in the caudal segment of the saddle (*P*<0.001). Although differences in absolute values were low, both in trot (*P*<0.05) and in canter (*P*<0.01) average weight for all 3 segments of the saddle was lower in female than in male riders (e.g. averaged pressure recorded for the middle segment: trot 1.16±0.05 and 1.14±0.03 N/m^2, canter 1.20±0.05 and 1.15±0.03 N/m^2 for male and female riders, respectively; Figure 4).

4. Discussion

The current study did neither demonstrate differences in the physical effort and stress response between male and female riders nor in the pressure exerted onto the

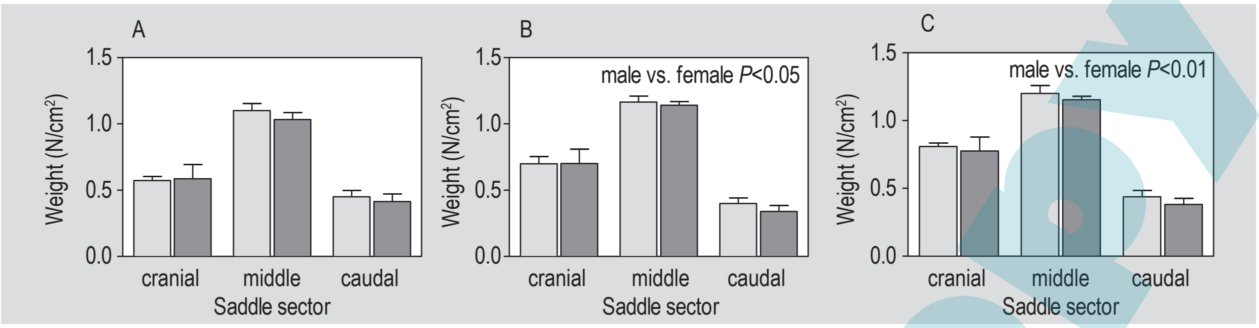

Figure 4. Average pressure in the cranial, middle and caudal segment of the saddle of horses ridden by either a male or a female rider in (A) walk, (B) trot and (C) canter. Differences between male and female riders are indicated in the figures, differences between saddle sectors for walk, trot and canter *P*<0.001.

horses back and the horses' stress response when ridden by either a male or female rider. Jumping a course of obstacles and the warm-up for jumping elicited a stress response in horses. This was clearly indicated by an increase in salivary cortisol concentrations and a decrease in the HRV variables SDRR and RMSSD. The increase in heart rate during the same time can partly be interpreted as a stress response, but is also due to physical activity during the equestrian tasks. The stress response caused by being ridden in horses is in agreement with previous studies (Becker-Birck *et al.*, 2012; Ille *et al.*, 2013; Schmidt *et al.*, 2010a; Von Lewinski *et al.*, 2013). Based on salivary cortisol concentrations riding is only a moderate stressor for horses and cortisol concentration remain below those reached in response to other potentially stressful situations, such as road transport (Schmidt *et al.*, 2010b,c), weaning of foals (Erber *et al.*, 2012) or parturition in mares (Nagel *et al.*, 2012). A moderate stress response in ridden horses may enable the animals to successfully meet the demands of equestrian sports. The stress response of the horses did in no way differ when they were ridden by a male versus a female rider and the curves depicting changes in cortisol concentration, heart rate and HRV were close to identical. The sex of their riders did thus not affect the horses' stress response and it is unlikely that it will affect the horses´ performance in equestrian competitions.

A stress response in the riders in response to the equestrian tasks of the study was not evident with regard to cortisol release and based on decreases in HRV it was much less pronounced than in their horses at the same time. Cortisol release of riders in previous studies depended on the riders' experience and on the equestrian tasks demanded. Thus, a clear increase in salivary cortisol concentrations has been demonstrated in highly experienced riders during training and performance of classical dressage (Von Lewinski *et al.*, 2013), but also in less experienced riders jumping a course of obstacles of similar difficulty as in the present study (Ille *et al.*, 2013). Neither cortisol nor HRV differed between male and female riders indicating that equestrian tasks, at least at the level demanded in our study, do not elicit a different stress response in male and female riders. The near identical increase in heart rate of the two rider groups shows that also the physical demands of the study were identical for riders of both groups. The jumping course resembled a competitive situation at medium level. More pronounced competitive demands might have induced a stress response in riders as shown previously (Ille *et al.*, 2013; Von Lewinski *et al.*, 2013). It cannot be excluded that such a stress response might at least in part differ between male and female riders. The hypothalamo-pituitary-adrenal response to physical exercise does not differ between men and women, while adult men respond to psychological stress with a greater increase in cortisol release than women (Friedmann and Kindermann, 1989; Kirschbaum *et al.*, 1992; Kudelka and Kirschbaum, 2005). The equestrian tasks of the current study clearly required physical activity as demonstrated by an increase in heart rate but there is no evidence that they were perceived as a psychological stressor by the riders.

Our results are valid for moderate demands in equestrian show jumping. More pronounced stress responses may be elicited when advanced tasks are required from the horses and their riders. This has already been demonstrated for equestrian dressage (Von Lewinski *et al.*, 2013). With increasing difficulty in show jumping, experience of the horse and rider will become more important than with the moderate level challenges in the current study. This will give individual, experienced riders an advantage but it is unlikely that such an advantage in competitions is more pronounced for riders of one sex versus the other.

In a small number of riders, the pressure distribution exerted via the saddle onto the back of the horse was analysed. Saddle pressure distribution is influenced by the body shape of the horse (De Cocq *et al.*, 2006). To standardise the measuring procedures only one horse was used for saddle pressure analysis in our study. Availability of the horse limited the number of riders that could be included into this part of the study. Average pressure in different saddle segments in previous studies showed a more pronounced and repeatable difference than minimal and maximal values in a study comparing different saddles types. It was thus considered the most relevant measurement (Byström *et al.*, 2010a,b) and was also analysed in the present study. Sitting, but not rising trot was investigated because rising trot is associated with a less stable seat of the rider in the saddle (De Cocq *et al.*, 2009b, 2010; Peham *et al.*, 2010).

Average pressure exerted onto the horse's back was highest in the middle third and lowest in the caudal third of the saddle. This was true for male as well as for female riders. A small but significant difference between male and female riders existed in trot and canter with the pressure exerted by women riders slightly lower in all three measured segments compared to men. Because weight of the rider strongly affects saddle pressure (Jeffcott *et al.*, 1999), this is most likely due to the lower average weight of women versus men and does not indicate a different seat of male and female riders in the saddle. The force acting on the back of the horse is further influenced by the horse's velocity (De Cocq *et al.*, 2006, 2009a), explaining why no difference between male and female riders existed in the walking horse. Saddle pressure is also affected by the skill of the rider and his ability to follow the locomotion of the horse with a more stable and balanced position in experienced riders (Clayton *et al.*, 2011; Lagarde *et al.*, 2005; Peham *et al.*, 2001; Terada, 2000). To exclude effects of rider experience, in the present study all riders were in the same stage of their equestrian training and always male and female riders with nearly equal experience rode the same horse. Rider effects on the horse are primarily exerted via the riders' seat and aids. Depending on the seat, signals from the rider to the horse may become more or less precise and consistent (Greve and Dyson, 2013). The lack of seat differences between male and female riders is thus in agreement with a similar cardiovascular and adrenocortical response in horses ridden by men and women.

Average pressure under the saddle was of a similar magnitude as reported by Meschan *et al.* (2007), however, in that study pressure between the cranial and middle saddle segment differed only slightly. As recordings of that study were made on a treadmill, this might have caused the rider to lean more forward than on a moving horse. In our study, recordings were only made on a straight line. However, no differences in saddle pressure distribution between straight and curved lines were found previously (Werner *et al.*, 2002) and thus seat differences between male and female athletes riding on curved lines are unlikely.

In conclusion, the current study does not demonstrate fundamental differences in the physical effort and stress response to equestrian tasks in show jumping and in the pressure exerted onto the horse via the saddle in walk, trot and canter between male and female riders. Horses respond to riding with a moderate stress response as indicated by increased salivary cortisol concentrations and decreased HRV but this response of the horse is similar with male and with female riders. Thus riding theories and principles developed largely for male riders can also be applied to female riders.

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