Journal of Equine Veterinary Science 35 (2015) 668–672

Contents lists available at ScienceDirect

Journal of Equine Veterinary Science

journal homepage: www.j-evs.com

Original Research

Riding Simulator Training Induces a Lower Sympathetic Response in Riders Than Training With Horses

Natascha Ille [a,*], Mareike von Lewinski [a], Christine Aurich [b], Regina Erber [b], Manuela Wulf [a], Rupert Palme [c], Bill Greenwood [d], Jörg Aurich [e]

[a] Graf Lehndorff Institute, Vetmeduni Vienna, Vienna, Austria
[b] Artificial Insemination and Embryo Transfer, Vetmeduni Vienna, Vienna, Austria
[c] Biochemistry, Vetmeduni Vienna, Vienna, Austria
[d] Racewood Ltd, Tarporley, UK
[e] Obstetrics and Reproduction, Vetmeduni Vienna, Vienna, Austria

A R T I C L E I N F O

Article history:
Received 10 March 2015
Received in revised form 5 June 2015
Accepted 14 June 2015
Available online 20 June 2015

Keywords:
Horse
Riding simulator
Show jumping

A B S T R A C T

Recently, equestrian riding simulators have become available for dressage, jumping, polo, or racing. In this study, we have compared salivary cortisol, heart rate, and heart rate variability (HRV) variables, standard deviation of beat-to-beat interval and root mean square of successive beat-to-beat differences, in 12 riders jumping a course of obstacles on a horse and on a riding simulator. Salivary cortisol concentrations from 60 minutes before to 60 minutes after simulator training were higher ($P < .05$) than those during training with a horse but did not change acutely with the simulated or real show jumping efforts. This indicates that the novel situation of simulator training was perceived as more stressful than routine training with a horse. Heart rate of the riders increased both on a horse and on a simulator ($P < .001$) but reached significantly higher values on the horse versus the simulator (175 ± 3 vs. 123 ± 5 beats/min, $P < .01$). Both HRV variables decreased ($P < .001$) during the simulated course and on a horse. From 30 minutes before to 30 minutes after the jumping tests, HRV variables were higher in association with the simulated course versus the course jumped with a horse (standard deviation of beat-to-beat interval, $P < .05$; root mean square of successive beat-to-beat differences, $P = .056$). The changes in heart rate indicate that simulator training required less physical effort than training on a horse. Based on differences in HRV, training with a horse was associated with a more pronounced sympathetic tone than simulator training. Although simulator training in principle mirrored the situation on a horse, the demands on a horse were more complex.

1. Introduction

Simulator-based training is used in a broad variety of fields. Although flight simulators for the training of air pilots are well established [1], simulators are gaining increasing importance to train diagnostic and surgical skills in medicine [2,3] and veterinary medicine [4]. Although the first riding simulator was developed over 25 years ago [5], such systems have not been widely used in equestrian training. Riding simulators can contribute to an objective assessment of the rider's position in the saddle [6,7] and the signals (aids) through which the rider controls the horse [8]. Schooling both the seat of the rider and consistency of the rider's aids on a simulator will contribute to improving equestrian performance [9]. In addition, horse riding simulators have been suggested to improve physical abilities and coordination of elderly people [10,11], children with cerebral disease [12],

* Corresponding author at: Natascha Ille, Graf Lehndorff Institute, Vetmeduni Vienna, Veterinärplatz 1, Vienna, Austria.
E-mail address: Natascha.ille@vetmeduni.ac.at (N. Ille).

0737-0806/$ – see front matter © 2015 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.jevs.2015.06.018

patients with chronic back pain [13] and to reduce anxiety in novice riders [14]. Recently, a new generation of simulators have become available which are aimed specifically at equestrian training [8]. They can be programmed for dressage, show jumping, polo, or racing and respond interactively to the aids of the rider. To the best of our knowledge, simulator-based training has not been compared to equestrian training with horses. Horse riding is both a physical and emotional challenge for the rider [15–19]. To what extent the demands of horse riding are mirrored by simulator training is so far unknown.

Continuous recording of heart rate is a simple technique for the evaluation of physical efforts. Heart rate variability (HRV), that is, slight variations in the beat-to-beat interval represent the balance of the sympathetic and parasympathetic branch of the autonomous nervous system on the sinus node of the heart. Decreases in HRV indicate a shift toward sympathetic dominance as occurs during a stress response while increased HRV is a result of parasympathetic dominance [20]. Physical efforts and stress situations also stimulate cortisol release from the adrenal cortex. Cortisol can be analyzed in blood plasma but more easily in saliva. In addition, salivary cortisol represents the nonprotein-bound and thus biologically active fraction of total plasma cortisol [21].

In this study, we have analyzed heart rate, HRV parameters, standard deviation of beat-to-beat interval (SDRR) and root mean square of successive beat-to-beat differences (RMSSD), and salivary cortisol concentration in riders jumping a course of obstacles with a horse and riding a virtual course of obstacles on a riding simulator. We hypothesized that a jumping simulator elicits a near identical physical effort in riders but a lower stress response than jumping with a horse.

2. Materials and Methods

2.1. Riders

The riders participating in this study were trainees in a 2-year program at the Brandenburg State Stud in Neustadt (Dosse), Germany ($N = 12$, six female and male each). Age was 21.5 ± 1.4 and 19.8 ± 2.2 years for female and male riders, respectively. As ranked by their trainer, all riders had nearly the same level of experience. On the scale of the German Equestrian Federation for equestrian competitions from 1 (E = entry level) to 5 (S = advanced or difficult level), they were ranked as level 3 (L). The riders were used to ride several horses nearly every day but had never trained on a riding simulator before. Informed consent was obtained from all riders before they participated in the study. None of the riders reported health problems throughout the study period.

2.2. Horses and Riding Simulator

The horses participating in this study were all geldings of the Brandenburg State Stud at Neustadt (Dosse), Germany, used in the riding school of the stud. Age of the horses was 11.0 ± 3.2 years. They were kept in individual loose boxes on straw or wood chippings and fed oats and pelleted concentrates three times daily and hay twice daily. Water was freely available at all times.

The riding simulator used in the study was developed for training riding abilities by imitating horse movements (interactive jumping and cross-country simulator; Racewood Equestrian Simulators, Tarporley, UK). The simulator can be controlled by leg and rein pressure from the rider and with independently moving head, neck, and body it simulates the reaction of a horse to any action of the rider. Besides riding in all gaits, the simulator can imitate jumping obstacles viewed on an interactive screen in front of the rider which gives also information about the distance to the next obstacle.

2.3. Experimental Design and Procedures

All riders had to accomplish a jumping course on a horse and simulate a jumping course on the jumping simulator. For 60 minutes before performing the jumping course on a horse and the simulated jumping course, the participants refrained from any physical activity. All riders participated in the test on a horse first and in the riding simulator test 10 months thereafter.

All tests on horses were performed in the same indoor area at the Brandenburg State Stud to which the riders and the horses were familiar. After preparing their horses, the riders mounted and walked to the arena where the warmup started with walk (5 minutes), trot (3 minutes), and canter (3 minutes) followed by jumping two obstacles at lower height. The riders then jumped a standardized jumping course with their horse (eight obstacles; height, 83–90 cm; length of the course, 310 m; average riding speed, 290 m/min). Saliva for cortisol analysis was taken at 60, 30, and 15 minutes before and at 0, 15, 30, and 60 minutes after the jumping course. Heart rate was recorded continuously from 60 minutes before until 60 minutes after jumping the course.

Tests on the riding simulator were performed at the Equitana Equestrian Fair at Essen, Germany. After resting for 1 hour, riders mounted the simulator. They started with a warmup phase (3 minutes) and one test obstacle followed by the jumping course of 13 obstacles. Theoretical length of the course was 540 m, height of the obstacles was between 90 and 110 cm, and theoretical riding speed was 270 m/min. Samplings of saliva and heart rate recordings were performed as for the test on a horse.

Tests on horses and simulator were always performed at the same time of the day between 10 AM and 12 AM.

2.4. Cortisol Analysis

For cortisol analysis, saliva was collected with cotton rolls (Salivette cortisol; Sarstedt, Nümbrecht-Rommelsdorf, Germany), which the riders placed in their mouth as described [14,15]. Salivettes were centrifuged at 1000*g* for 10 minutes, and saliva was aspirated and frozen at −20°C. For determination of cortisol concentration, a direct enzyme immunoassay without extraction [22] was used as described [23]. The minimal detectable concentration of the assay was 0.04 ng/mL, and intra-assay and interassay coefficients of variation were 4.5% and 12.5%, respectively.

2.5. Heart Rate and Heart Rate Variability

The cardiac beat-to-beat (RR) interval was recorded with mobile heart rate monitors (S810i; Polar, Kempele, Finland), following the manufacturer's recommendations. From the recorded RR intervals, heart rate and the HRV parameters, SDRR and RMSSD, were calculated with the Kubios HRV software (Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland). An artifact correction was made as described [23], and data were detrended following established procedures [24]. For comparison of heart rate and HRV, 1-minute intervals were analyzed at 30 and 15 minutes before the jumping course, during the first minute of the jumping course and at 15 and 30 minutes thereafter.

2.6. Statistical Analysis

Statistical analyses were performed with the SPSS statistics package (version 20.0; IBM, Armonk, NY). All data were normally distributed (Kolmogorov–Smirnov test). Changes in heart rate, SDRR, RMSSD, and salivary cortisol were analyzed by analysis of variance using a general linear model for repeated measures with horse and simulator test as between subject factors. A P value of $<.05$ was considered significant. All data given are the mean ± standard error of the mean.

3. Results

3.1. Cortisol

Salivary cortisol concentration in riders was significantly higher ($P < .01$) from 60 minutes before until 60 minutes after the jumping simulator test compared to the equestrian tasks on the horse. Cortisol concentration tended to decrease over time with a small and transient increase detected in response to the simulator test (changes over time, $P < .01$; interactions test × time, not significant; Fig. 1).

3.2. Heart Rate and Heart Rate Variability

Heart rate of the riders increased during the jumping course both on a horse and on a riding simulator and returned to baseline values within 30 minutes thereafter ($P < .001$ over time). The increase was significantly more pronounced when riders were jumping with a horse compared to the jumping simulator (maximum values: 175 ± 3 and 123 ± 5 beats/min, respectively, $P < .001$; interactions group × time, $P < .001$; Fig. 2A).

The HRV variable SDDR was higher before, during, and after the riding simulator test versus the test on a horse ($P < .05$), and this difference nearly reached statistical significance for RMSSD ($P = .056$). Both SDRR and RMSSD decreased when riders were jumping an obstacle course on a horse and imitating a jumping course on a simulator ($P < .001$ over time) and increased to pretest baseline values thereafter (Figs. 2B and 2C). The SDRR of riders decreased from 69 ± 14 to 28 ± 6 ms and the RMSSD from

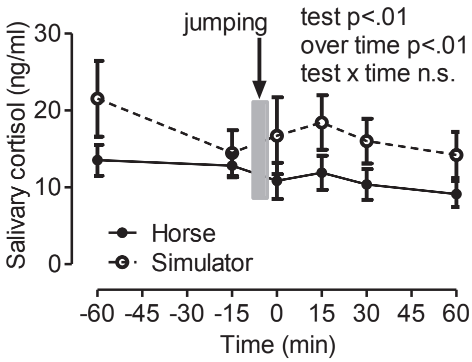

Fig. 1. Concentration of cortisol in saliva of riders (N = 12) before and after jumping a course of obstacles on a horse or imitating a jumping course on a riding simulator, gray bar indicates time of jumping course, values are the mean ± standard error of the mean. n.s., not significant.

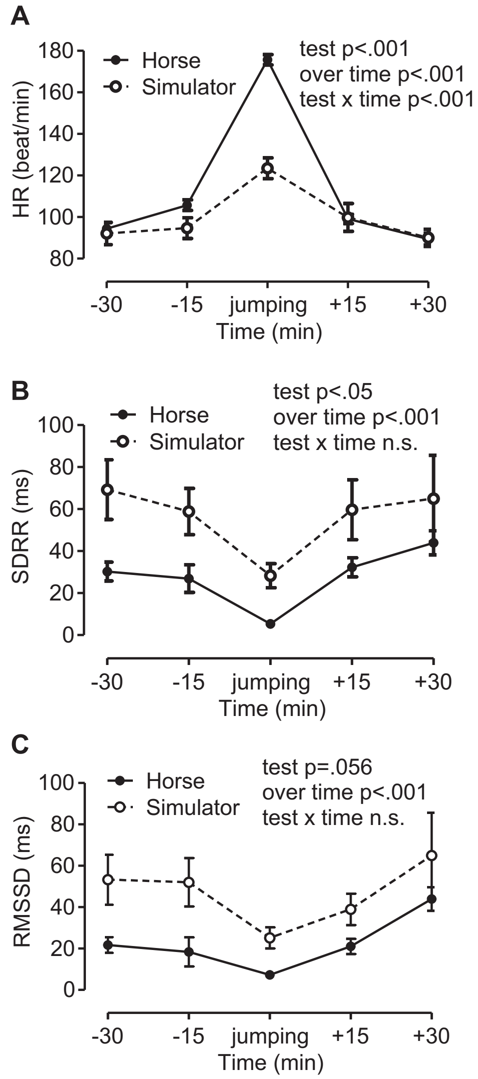

Fig. 2. (A) Heart rate (HR) and heart rate variability parameters, (B) standard deviation of beat-to-beat interval (SDRR), and (C) root mean square of successive beat-to-beat differences (RMSSD) of riders (N = 12) before, during, and after jumping a course of obstacles on a horse or imitating a jumping course on a riding simulator; values are the mean ± standard error of the mean.

53 ± 12 to 12 ± 5 ms in the horse test compared to 30 ± 4 to 5 ± 1 ms and 22 ± 4 to 7 ± 2 ms on the jumping simulator. Curves for SDRR and RMSSD for both test situations were largely parallel, and no significant interactions of test × time were detected.

4. Discussion

Although riding a horse and training on a riding simulator in principle request the same activities from riders, the two situations differ in several aspects. The changes in heart rate demonstrate that the physical effort of riding a horse over a jumping course was clearly more pronounced than a simulated jumping course on the riding simulator. Peak heart rate on a horse was in the same order of magnitude as in previous studies on riders during show jumping [16–18]. The theoretical speed on the simulator was only slightly slower than speed in jumping with a horse. Physical demands on the riding simulator can certainly be raised by increasing height of the virtual obstacles and speed of the simulated horse or by programming a requirement for more pronounced propulsive aids of the rider to make the simulator "approach" the obstacles. Such a simulation would, however, mirror an advanced level course and not the competition entry level tasks demanded from the riders on a horse in the present study.

As expected from previous studies [17,18], the HRV parameter SDRR decreased in riders jumping the obstacles with a horse and a decrease in RMSSD nearly reached statistical significance. Heart rate variability decreases to a certain degree with increasing heart rate [25]. However, although heart rate of riders differed only during the actual test situation, that is jumping the real and virtual obstacles, HRV was lower also before and after the jumping efforts on a horse compared to the riding simulator test. Heart rate variability thus did not simply mirror heart rate. A reduction in HRV indicates increased sympathetic activity, decreased parasympathetic tone, or a combination of both [20]. Our data thus suggest more pronounced sympathetic dominance in riders handling and riding horses compared to training on a simulator. Ridden horses, but not the simulator in our study, at any time may act in an unforeseen way (i.e., refuse a fence, spook, or refuse to cooperate) and thus require an immediate and unplanned response of the rider. The rider will thus show a higher level of alert on a horse than when training on a simulator. This is even more remarkable as the riders in our study were well habituated to riding a horse and the riding test took place in familiar surroundings. In contrast, the riders had never trained on a simulator before and the simulator test took place in a novel environment. A more pronounced sympathetic activity in the latter but not the first test might therefore have been expected.

Salivary cortisol concentration in riders did not increase consistently in response to the test situations which were thus not perceived as major acute stressors. In contrast, a performance of classical dressage at advanced level always caused a clear increase in salivary cortisol concentrations in riders and in their horses [19]. Whether equestrian tasks represent a stressor for riders depends on the degree of difficulty. The jumping courses on the simulator and on the horse were at the lower level of equestrian show jumping competitions and thus neither technically difficult for the riders nor did the physical effort exceed in any way the riders' limit in physical fitness.

Although salivary cortisol concentration in riders did not change markedly in response to the tasks of the present study, cortisol levels were higher on the day of the simulator test versus the horse-riding test. We suggest that this due to the new environment associated with the simulator test and the novel challenge of the riding simulator versus the routine task of riding a horse. The situation may be comparable to magnetic resonance image scanning in medicine, a nonpainful but for most patients, novel procedure. Test person had elevated cortisol concentrations immediately preceding an initial magnetic resonance image scan but not before follow-up scans, that is the stress response decreased with consecutive scans [26]. In a similar way, veterinary students responded with an increased cortisol release when asked to perform a gynecologic examination in a mare for the first time but much less in subsequent examinations [27]. It would thus be of interest also to study the cortisol response of riders during repeated simulator training sessions.

Unfortunately, it was not possible to perform the riding simulator and the horse riding test at the same location and time. Therefore, the order of tests could not be arranged in a Latin square design, and all riders were studied first on a horse and second on the riding simulator. The experiment was thus not randomized with regard to all aspects of the experimental design. However, all riders showed a high degree of physical fitness already at the time of the first test, and although they gained further experience with ongoing training, it is unlikely their physical fitness did change between the two tests. Because the cortisol release on the day of simulator training has to be largely interpreted as the response to a completely novel situation, it is unlikely that a shorter time period between the two tests would have changed the results.

Although it cannot be totally excluded that the order of tests may have influenced cortisol release, it did not affect basal heart rate which was similar on both occasions. Differing changes in heart rate induced by the different test situations thus reflect true differences between the equestrian tasks of the study. Any bias with regard to HRV should have caused lower HRV in the novel test on the simulator versus the routine task on a horse. In contrast, HRV was lower in the test on the horse, indicating that differences in HRV of riders between the situations on a horse versus a riding simulator are true.

In conclusion, training on an equestrian show jumping simulator was physically less demanding and induced less sympathetic activity than riding a horse over a course of obstacles at entry level of show jumping competitions. Riding simulators may therefore be more adequate for analyzing and schooling the rider's seat, position, movements, and aids than for physical fitness training. They are thus a useful and less accident-prone addition to direct training with horses. However, simulator training can only partially imitate the complex training situation on a horse.

References

[1] Baarspul M. A review of flight simulation techniques. Prog Aerosp Sci 1990;27:1–120.
[2] Stefanidis D. Optimal acquisition and assessment of proficiency on simulators in surgery. Surg Clin North Am 2010;90:475–89.
[3] Maiss J, Naegel A, Hochberger J. The European experience—current use of simulator training in Europe. Tech Gastrointest Endosc 2011; 13:126–31.
[4] Price A, Voute L, Hunt I, Love S. Teaching rectal examination of the equine intestinal tract to veterinary undergraduates: validation of a simulator as an alternative to live horses. Res Vet Sci 2003;74:18.
[5] Jouffroy JJ. L'analyse et la restitution des sensations par simulation en équitation: programme Persival. Sci Sports 1991;2:129–31.
[6] Longhurst K, Lesniak K. Postural asymmetry of the rider whilst static and in sitting trot. J Vet Behav 2013;8:e15.
[7] Bouloc C, Biau S. Incidence d'une prise en charge ostéopathique globale du cavalier sur son fonctionnement - étude préliminaire [Effects of osteopathic treatment on the functioning of riders—preliminary studies]. Proc 41. Journée de la Recherche Équine, Saumur, France. Institut français du cheval et de l'équitation. p. 46–58, http://www.haras-nationaux.fr/fileadmin/bibliotheque/publications/ProgrammeJRE2015web_janvier2015; 2015. accessed 11th May 2015.
[8] Nevison CM, Hughes A, Cole MD. Variability in lower leg aids used to achieve gait transitions on a dressage simulator. J Vet Behav 2011;6: 294.
[9] Galloux P, Jinenez M, Richard N, Dronka T, Leard M, Jouffroy JL, Chollet A. Les mouvements de la selle aux trois allures - application à la reproduction des allures par le simulateur Persival [Movements of the saddle in three gaits—usefulness for reproducing the gaits with the Persival simulator]. Equathlon 1995;7:22–7.
[10] Mitani Y, Doi K, Yano T, Sakamaki E, Mukai K, Shinomiya Y, Kimura T. Effect of exercise using a horse-riding simulator on physical ability of frail seniors. J Phys Ther Sci 2008;20:177–83.
[11] Kim S, Yuk GC, Gak H. Effects of the horse riding simulator and ball exercises on balance of the elderly. J Phys Ther Sci 2013;25:1425–8.
[12] Lee CW, Gil S, Na SS. The effects of hippotherapy and a horse riding simulator on the balance of children with cerebral palsy. J Phys Ther Sci 2014;26:423–5.
[13] Yoo JH, Kim SE, Lee MG, Jin JJ, Hong J, Choi YT, Kim MH, Jee YS. The effect of horses simulator riding on visual analogue scale, body compostition and trunk strength in the patients with chronic lower back pain. Int J Clin Pract 2014;68:941–9.
[14] Demarie S, Minganti C, Piacentini MF, Parisi A, Cerulli C, Magini V. Reducing anxiety in novel horse riders by a mechanical horse simulator. Med Sport 2013;66:179–88.
[15] Westerling D. A study of physical demands in riding. Eur J Appl Physiol 1983;50:373–82.
[16] Devienne MF, Guezennec CY. Energy expenditure of horse riding. Eur J Appl Physiol 2000;82:499–503.
[17] Ille N, von Lewinski M, Erber R, Wulf M, Aurich J, Möstl E, Aurich C. Effects of the level of experience of horses and their riders on cortisol release, heart rate and heart rate variability during a jumping course. Anim Welf 2013;22:457–65.
[18] Ille N, Aurich C, Erber R, Wulf M, Palme R, Aurich J, von Lewinski M. Physiological stress responses and horse rider interactions in horses ridden by male and female riders. Comp Exerc Physiol 2014; 10:31–138.
[19] Von Lewinski M, Biau S, Erber R, Ille N, Aurich J, Faure JM, Möstl E, Aurich C. Cortisol release, heart rate and heart rate variability in the horse and its rider: different responses to training and performance. Vet J 2013;197:229–32.
[20] Von Borell E, Langbein J, Despres G, Hansen S, Leterrier C, Marchand-Forde J, Marchand-Forde R, Minero M, Mohr E, Prunier A, Valance D, Veissier I. Heart rate variability as a measure of autonomic regulation of cardiac activity for assessing stress and welfare in farm animals—a review. Physiol Behav 2007;92: 293–316.
[21] Riad-Fahmy D, Read GF, Walker RF. Salivary steroid assays for assessing variation in endocrine activities. J Steroid Biochem 1983; 19:265–72.
[22] Palme R, Möstl E. Measurement of cortisol metabolites in faeces of sheep as a parameter of cortisol concentration in blood. Int J Mammal Biol 1997;62(Suppl. II):192–7.
[23] Schmidt A, Aurich J, Möstl E, Müller J, Aurich C. Changes in cortisol release and heart rate and heart rate variability during the initial training of 3-year-old sport horses. Horm Behav 2010; 58:628–36.
[24] Tarvainen MP, Ranta-aho PO, Karjalainen PA. An advanced detrending method with application to HRV analysis. IEEE Trans Biomed Eng 2002;49:172–5.
[25] Hottenrott K, Hoos O, Esperer HD. Herzfrequenzvariabilität und Sport: Aktueller Stand [Heart rate variability and sport: current status]. Herz 2006;31:544–52.
[26] Peters S, Cleare AJ, Papadopoulos A, Fu CHY. Cortisol response to serial MRI scans in healthy adults and in depression. Psychoneuroendocrinology 2011;36:737–41.
[27] Nagel C, Ille N, Erber R, Aurich C, Aurich J. Stress response of veterinary students to gynaecological examination of horse mares: effects of simulator-based and animal-based training. Proc 19. Annual Conference of the European Society for Domestic Animal Reproduction; 2015 (in press).