Author(s): Hyttinen, Anne-Maarit; Ahtiainen, Juha P.; Häkkinen, Keijo

Title: Oxygen uptake, heart rate and blood lactate levels in female horseback riders during the obstacle test track

Year: 2020

Version: Accepted version (Final draft)

Oxygen uptake, heart rate and blood lactate levels in female horseback riders during the obstacle test track

Hyttinen, A-M[a*], Ahtiainen, JP[a], Häkkinen, K[a]

[a]*Neuromuscular Research Center, Biology of Physical Activity, Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland*

Correspondence:

Anne-Maarit Hyttinen
Neuromuscular Research Center,
Biology of Physical Activity,
Faculty of Sport and Health Sciences,
P.O. Box 35
FI-40014, University of Jyväskylä, Finland
e-mail: anne.a-m.hyttinen@jyu.fi

Tel: +35850 590 4303

Juha Ahtiainen

Neuromuscular Research Center,
Biology of Physical Activity,
Faculty of Sport and Health Sciences,
P.O. Box 35
FI-40014, University of Jyväskylä, Finland

Keijo Häkkinen

Neuromuscular Research Center,
Biology of Physical Activity,
Faculty of Sport and Health Sciences,
P.O. Box 35
FI-40014, University of Jyväskylä, Finland

Oxygen uptake, heart rate and blood lactate levels in female horseback riders during the obstacle test track

The purpose of this study was to examine endurance performance by recording oxygen uptake, heart rate and blood lactate during the obstacle test track, equivalent to competitive performance in female horseback riders. In total 42 female riders participated in the study (show jumping, SJ n=16, eventing, E n=26). Age, height and weight of the total group were 29.0(9.2) yrs, 1.68(0.06) m, and 68.1(10.3) kg, respectively. Participants rode a minimum of 4 times per/week, and the riding level was from national to international. VO_2peak/VO_2mean and HRpeak/HRmean of the total group during the obstacle test track (OTT) were 34.4(5.0)/26.4(4.0) ml/kg/min and 184.4(9.6)/178.1(10.2) bpm. BLa concentration of the total group increased during the OTT to 7.6(2.2) mmol/L. No significant differences were observed between SJ and E in any endurance performance variables during the OTT. The results indicated that the previous experience in SJ and/or E riding training did not lead to any differences in the present rider´s physical loading during OTT. As the OTT appeared to be very strenuous to the present riders, it might be appropriate to design both SJ and E horseback riding training and additional endurance training to support equestrian sport specific performance in situations of competition.

Keywords: Equestrian sports, endurance performance, show jumping, eventing

Subject classification codes: include these here if the journal requires them

Introduction

Horse racing is a unique constitution of the co-operation between human and horse. One of the horse racing forms, horseback riding, is a popular hobby and form of sport worldwide. The most well-known types of equestrian sport are dressage, show jumping and eventing riding. Dressage riding is a highly skilled exhibition form of riding competitions, where the horse and rider perform a highly skilled series of predetermined movements (“FEI dressage,“ 2019). Show jumping is the competitive riding event so that the horse and rider overcome obstacles on the course within a given time (“FEI jumping,“ 2019). Eventing is a combination that all competitors must take part in each of several contests, dressage, show jumping and cross-country, where the immovable cross-country obstacles are crossed in a natural environment (“FEI eventing,“ 2019).

The training process and performance outcomes of the horseback riding are highly dependent on effective rider-horse interactions and physical skills of the horseback rider and horse. Sensitivity of the horse enables to detect and react to all changes in body position, muscular strength and tension, respiration and even to the heart rate of a horseback rider (Wolframm & Micklewright, 2009). The sensitivity and training level of the horse specify the physical demands of the rider. In addition, the type and level of horseback riding specify the content of the physical fitness of the rider. A show jumper (or eventing rider) must have the technical skills and courage to jump large fences as well as the athletic ability to handle the sharp turns, explosive jumps and rhythm of the canter necessary to navigate the most difficult courses (Wolframm & Micklewright, 2009).

Previous studies have largely focused on metabolic and / or cardiovascular changes in different gaits of horse (Beale et al., 2015; Devienne & Guezennec, 2000; Fabritius & Elovainio, 1978; Ille et al., 2014; Jeukendrup & van Diemen, 1998; Roberts et al., 2010; Sainas et al., 2016; Westerling, 1983; Wright & Peters, 2008). However, studies of physical performance characteristics of the horseback rider during the obstacle course are scarce. It is known that oxygen uptake and heart rate of the rider increase in relation to the speed of the horse (Devienne & Guezennec, 2000; Fabritius & Elovainio, 1978; Hyttinen, 2015; Jeukendrup & van Diemen, 1998; Roberts et al., 2010; Westerling, 1983; Wright & Peters, 2008). The heart rate increases also systematically as the speed (gaits) of the horse increases (Jeukendrup & van Diemen, 1998) and the heart rate is at its highest during the working trot, canter and jumping (Devienne & Guezennec, 2000; Elovainio & Fabritius, 1978; Roberts et al., 2010; Westerling, 1983; Wright & Peters, 2008). Maximal oxygen uptake (VO_2max) values of horseback riders from the novice to international level are approximately 32-48 ml/kg^{-1}/min^{-1} (Fabritius & Elovainio 1978; Hyttinen 2015; Hyttinen & Häkkinen 2019; ~~M.~~ Meyers 2006; Meyers & Sterling 2000; Westerling 1983). A mean value of 75 % of VO~~2~~$_2$max during show jumping was reached in two earlier studies (D. Westerling 1983; Devienne & Guezennec 2000). The heart rate level can reach above 80 - 90 % of the maximum at times in a competitive condition (Gutierrez Rincón et al. 1992; Westerling 1983). On the other hand, Sainas et al. (2016) have concluded that a typical horseback riding session imposes only light or moderate loading to the aerobic and anaerobic energy systems. It is also known that a physically and technically skilled rider can ride more economically (Hyttinen, 2015).

However, it is unclear how specific riding background of several years affects the physical performance characteristics of a horseback rider. In addition, more extensive and detailed information is needed about physical performance variables of horseback riders during the obstacle test track. This information may also contribute to the development of a specific additional training program for horseback riders. These types of measurements cannot be performed in a real competitive situation, because it is not allowed under the current jumping competition rules ("FEI jumping," 2019). In addition, effects of long lasting show jumping performance on physiological performance variables of horseback rider cannot measure in a real competitive situation. The purpose of the present study was to examine the physical fitness profile as well as acute physiological responses created by a long duration show jumping riding performance in the obstacle test track between the female show jumping and eventing riders.

Materials and methods

Participants

A total of 52 Finnish female show jumping (n=19) and eventing (n=33) horseback riders volunteered to participate in the study. The obstacle test track performance and all the measurements were performed by 42 horseback riders (SJ n=16, E n=26). Four "disqualifications" were caused by the refusals, two participants due to for the fall offs, two forgot the order of the obstacles (a jumping "map") and two riders had behaving problems of the horse. Physical characteristics and riding background (Mean ± SD) of female horseback riders are presented in Table 1. The participants rode a minimum of 4 times / week using their own or rented horse with the jumping level of minimum 1.09 ± 0.09 m (Table 1). The show jumping or eventing level of the participants were from the national to the international level. According to the classification of Williams & Tabor (2017) skill levels of the horse and rider were from novice to elite. The participants were free of acute and chronic illnesses. In addition, a cardiologist analyzed a health questionnaire and ECG from each participant. This study was conducted in accordance with the ethical standards of the complied Declaration of Helsinki and was approved by the Ethics Committee of the University of Jyväskylä.

Experimental design

The design of the obstacle test track and jumping orders were sent to all participants at least two weeks in advance. A familiarization session of the obstacle test track without a horse by walking was carried out before the actual horseback riding measurements. All measurements were performed in the same testing session in the order described below. Figure 1 describes the overall experimental design.

Obstacle test Track (OTT) (Figure 2) was designed by the international expert. This track was ridden like in a competition and it was ridden twice as similarly as possible. The course was built exactly similarly in every riding measurement by colors, obstacle models and placing of obstacles. The type of obstacles used in the test track were vertical obstacle and parallel oxer (Figure 2). The track building was documented by photographs and videos to ensure similarity.

Oxygen uptake during riding (VO_2^{riding}): Oxygen uptake was measured during the horseback riding by the battery-operated Oxycon Mobile® (Jäger, Würzburg, Germany). Oxycon Mobile® was strapped to the back of the participant allowing continuous data sampling (Figure 1). Data was transmitted telemetrically and recorded by a personal computer. The data collected every second was averaged in five seconds intervals, where VO_2^{riding}peak (the highest measured result in the test track) and VO_2^{riding}mean were analyzed. Maximal oxygen uptake (VO_2max) during the cycle ergometer test (CET) was also measured from those participants (about two weeks earlier) by Oxycon Mobile® and reported in detailed in another earlier publication (Hyttinen & Häkkinen, 2019).

Heart Rate (HR^{riding}) during the riding was measured with Polar H7 and H10 Heart Rate monitors for riders and horses (HRM, Polar Electro OY, Kempele, Finland). HR was recorded every one second during the warm up, test track and cooling down. In addition, HR^{riding}peak (the highest measured result in test track) and HR^{riding}mean was recorded. Trainer4Riding® ANALYTICS mobile app (www.trainer4riding.fi) was used to collect and analyse heart rate data (Figure 1). Trainer4Riding® ANALYTICS combines both the horse and the rider's heartbeat directly into the video, allowing to analyse the heart rate changes during riding on the track. The HR data collected every second was used when compared between the horse and rider, and five second averaged data when compared to VO_2 results.

Blood Lactate (BLa): Capillary blood samples were taken from the fingertip and used for determination of blood lactate at four time-points during the horseback riding test (Figure 1). Capillary blood samples were stored in the refrigerator at a temperature of about 4 to 6 degrees during the transport to the laboratory. Analyses were performed using the Biosen lactate analyzer (S_line Lab+, EKF Diagnostic, Magdeburg, Germany).

Statistical analysis

Descriptive data were generated for all variables and expressed as maximum and means ± standard deviations (SD). The IBM SPSS Statistics software (v. 20-24, IBM Corporation, Armonk, New York, USA) and the Microsoft Excel Program (Version Plus 2016, Microsoft Corporation, Redmond, WA, USA) were used for analyzes. The normality of the data was checked using the Kolmogorov-Smirnov test ($p<0.05$). The statistical significance between two experimental groups (Student's t-test) was accepted when $p<0.05$ to detect any differences within the species. Pearson correlation coefficients were calculated.

Results

Peak oxygen uptake (the highest VO_2^{riding} measured in OTT) of the present horseback riders during the total OTT was 34.4 ± 5.0 ml/kg/min. When comparing VO_2^{riding}peak results during the total OTT to VO_2max values measured in the maximal cycle ergometer test (CET) in the same participant group (VO_2max 31.8 ± 5.0 ml/kg/min, HR 184.4 ± 9.6 bpm, blood lactate 9.9 ± 2.2 mmol/L; data obtained from the study by Hyttinen & Häkkinen (2019)), VO_2^{riding}peak values were ≈ 110 % of VO_2max (Table 2). Respectively, VO_2^{riding}mean level in the present horseback riders during the total OTT was 26.4 ± 4.0 ml/kg/min (≈ 84 % comparing to VO_2max in CET) (Table 2). VO_2^{riding} levels analyzed separately from both riding rounds (1-2) during OTT, showed no significant differences in VO_2^{riding} levels between two participant groups during round 1 or 2 (Figure 3).

HR^{riding}peak of the present horseback riders during the total OTT was 185.0 ± 9.6 bpm which was ≈ 100 % compared to HRmax measured by CET (Table 3). Correspondingly, HR^{riding}mean was 178.1 ± 10.2 bpm (≈ 97 % compared to HRmax in CET) (Table 3). HR^{riding}mean during the total OTT in round 1 or round 2 were very similar with no significant differences between two participant groups (Figure 3). BLa concentrations of the total participant group immediately after the total OTT were 7.6 ± 2.2 mmol/L, which was ≈ 80 % compared to maximal lactate observed in CET (Table 3). There were no significant differences in BLa levels between the SJ and E groups in OTT. No significant differences were found during OTT or obstacle analysis at each obstacle in the HR of the horse or the rider between two participant groups (Table 4).

Discussion

The primary results showed that the present national and international level Finnish female show jumping (SJ) or eventing (E) riders did not differ significantly in the measured endurance characteristics in the obstacle test track (OTT) as one might have expected. There were no significant changes either in mean cardiorespiratory characteristics in the warm up and cooling down periods between two participant groups. The assumption was that eventing riders should have ridden OTT more economically, since riding training of eventing should involve more long-term riding and endurance type of training because of the characteristics of the eventing riding sport (Roberts et al. 2010; Douglas 2017). The present study showed that both participant groups used almost 100% of their heart rate and oxygen uptake (peak) already during the first round of riding. Although the duration of the competition type of show jumping performance was doubled in the present total OTT in order that steady-state of oxygen consumption could be achieved during jumping, there were no significant differences in any variables of endurance performance between the present SJ or E participant groups.

The duration of one riding round was approximately 76 seconds. A typical show jumping track in a normal competition is 60-90 seconds and it consists of 8-20 obstacles. It was assumed that the characteristics of OTT of this study would be the same as those of the actual competition track. Every mistake (refusals, circles or faults) on the obstacle track costs time, and makes changes in the riding rhythm, tempo and body balance of the horse and rider. Some previous studies have focused on physical characteristics of the horseback rider only in the optimal obstacle track (Perciavelle et al. 2014; Ille et al. 2014; Westerling 1983; Devienne & Guezennec 2000; Gutierrez Rincón et al. 1992; Roberts et al. 2010). It has been unclear how the lengthening of the obstacle track would affect the physical performance characteristics of a rider.

Devienne & Guezennec (2000) and Westerling (1983) came to the conclusion that an experienced rider uses during the jumping training a mean value ≈ 75 % of VO_2max. The HR of a rider can reach above 80 - 90 % of the maximum at times in a competitive situation (Gutierrez Rincón et al. 1992; Westerling 1983). The present total participant group reached in OTT round 1 a mean value of ≈ 73 % of VO_2max and VO_2^{riding}peak (the highest VO_2^{riding} measured in OTT) was ≈ 100 % of VO_2max. The riders used approximately a mean value 94 % of their HRmax and HR^{riding}peak was almost at the maximal level already during the first riding round. The percentage values of VO_2 and HR values of round 1 in the present total participant group were very similar compared to previous studies measured from experienced riders. However, the results of Westerling (1983) showed that top-level female horseback riders used only ≈ 61 % of their maximal oxygen uptake levels in the jumping track, even though heart rate would be over 90% of the maximum.

It is unclear why top level horseback riders have better oxygen uptake than amateur horseback riders. Few studies have noticed that additional endurance and/or strength training in horseback riders is not common (Devienne & Guezennec 2000; Roberts et al. 2010; Westerling 1983; Meyers & Sterling 2000; Terada et al. 2004; Hitchens et al. 2011; Douglas et al. 2017~~2~~). It has been suggested that differences in the oxygen uptake capacity should be found in the number of horses being ridden. Beale et al. (2015) and Sainas et al. (2016) have, however, concluded that the intensity of a typical horseback riding training session (≈ 60 min.) is from light to moderate, nor would it alone be sufficient to increase the oxygen uptake capacity, at least among novice riders with a low volume of weekly riding. Meyers (2006) investigated the effects of a 14-week riding intervention on the physical performance of horseback riders and concluded similarly as Beale et al. (2015) and Sainas et al. (2016) that riding alone is not enough to improve endurance capacity. The present SJ and E horseback riders rode at least 4-6 times a week approximately 1-4 hours per day depending on the number of horses. They had no systematic endurance or strength training background. Although a jumping training session increases oxygen consumption, it is not performed more than twice a week with the same horse. In addition, jumping exercises are typically short duration types of training and the overall load of training increases only moderately during the jumping training. Thus, a rider would need at least several horses and really intensive and well-designed horseback riding training sessions to develop her oxygen uptake only by riding without compromising the well-being of the horse.

The results of this study showed that when the duration and/or length of OTT increases, the load of the rider (and horse) during OTT progressively increases. The total mean duration of OTT of this study (round 1+round 2) was 152 ± 20 seconds. Interestingly, between riding rounds 1 and 2, VO_2^{riding}peak in the total participant group increased by 9.6 % and VO_2^{riding}mean increased even by 20.8 % compared to their VO_2max. In addition, VO_2^{riding}peak during riding in the total OTT was nearly 10 % more than that of VO_2max. That may indicate that it could be easier for the horseback rider to achieve maximal performance level during riding than in the cycle ergometer test. On the other hand, VO_2^{riding} could be lower during the first riding round, because steady-state oxygen consumption is not achieved in such a short time (Devienne & Guezennec 2000). It is also possible that horseback riding training may have focused “only” on the optimal competition performance to which the body of the rider (and horse) would need to adapt to. In this case, even minor changes in the duration in the obstacle track will increase the load of the rider and horse.

Heart rate (HR) levels in the present horseback riders of this study were near to 100 % of HRmax already at the end of round 1 and about 100 % of HRmax during round 2. HR levels increased progressively very similarly for both the horse and rider. The shape or optic of the obstacle did not produce any significant differences in the HR values of the horse or rider. An interesting observation in this study was that, when considered individually, the steady and technically correct and error-free riding in the present OTT produced approximately about the same HR for both the rider and horse, although the HR range of the horse (30-240 bpm/min) is wider than that of a human being (Geor et al. 2008). This observation requires further investigation. The variability of HR (HR^{riding}peak and HR^{riding}mean) of the horseback riders in this study between round 1 and round 2 were more moderate. HR^{riding}peak increased only by 1.4 % and HR^{riding}mean just by 5.4 % compared to HRmax in the total group of this study. Previous studies have speculated that a static riding posture, long-term maintenance of the body control and stress during the obstacle track may increase HR more than one would be expect (Devienne & Guezennec 2000; Westerling 1983; Gutierrez Rincón et al. 1992). Presumably, the maintenance of the predefined tempo and rhythm during the obstacle track and jumps as steady as possible (both the rider and horse) from the start to the finish would also increase HR. HR alone may not be the best way to evaluate the load of the horseback riding performance due to distractions. The relative difference between HR and VO~~2~~$_2$ in round 1 and round 2 could be due to fact that steady-state oxygen consumption during jumping is not achieved yet during round 1.

Blood lactate (BLa) levels of the total participant group was measured after the total OTT. BLa was not measured after the first round, because the riding performance was not interrupted so that the actual load in the total obstacle track could be determined. Previous studies have reported BLa levels of 4-8 mmol/L after the optimal obstacle track (duration 60-90 seconds) which are quite similar with the results of this study (Perciavelle et al. 2014; Roberts et al. 2010; Gutierrez Rincón et al. 1992). The present results obtained suggest that the BLa level increases progressively with the duration of OTT. After ≈ 2.30 min competition-like OTT the BLa levels of the present horseback riders were ≈ 79 % of BLa^{max}, which indicates that the load on the horseback riding performance in the present OTT has been high. Sainas et al. (2016) suggested that horseback riding can produce higher BLa values compared to the cycle ergometer test, because the rider actively uses also arm muscles for communicating with the horse. However, the aim of the horseback riding is to keep a stable and well balanced body and the hands of the rider would be able to follow closely the movements of the horse. The performance of riding would be as economical as possible and the skills of the horseback rider would be optimally utilized. Perciavelle et al. (2014) have concluded that increasing BLa levels during the obstacle track was associated with a significant worsening of attentional performance, especially reaction and execution time of the horseback rider.

The results of this study indicate that the present show jumping and eventing horseback riders were physically loaded almost maximally in riding during the present OTT. It has been reported that high levels of loading increase injury risks of riding, diminish reactivity and impair mental control (Perciavelle et al. 2014). It should also be noted that an unbalanced body of the horseback rider due to fatigue leads to extra stress for the horse and could increase muscle work of the horse to keep the rider and the horse in the proper balance (Devienne & Guezennec 2000).

It would seem that in the future attention should be paid both to the content of horseback riding training taking into account the type of horseback riding and to systematic additional endurance and/or strength training of horseback riders.

Acknowledgements

The authors would like to acknowledge the technical staff of the Neuromuscular Research Center, Biology of Physical Activity, in the Faculty of Sport and Health Sciences at the University of Jyväskylä involved in the project, the Finnish Riding Association and Trainer4Skills Oy Ltd. The authors also thank all the students who assisted in the data collection and all the participants who volunteered to make this project possible for their time and effort.

Declaration of interest statement

None of the authors declare any conflict of interest and the results of the present study do not constitute endorsement by the authors or the Neuromuscular Research Center.

References

1. Beale, L., Maxwell, N. S., Gibson, O. R., Twomey, R., Taylor, B., & Church, A. (2015). Oxygen cost of recreational horse-riding in females. *Journal of Physical Activity and Health*, 12, 808–813.
2. Devienne, M., & Guezennec, C. (2000). Energy expenditure of horse riding. *European Journal of Applied Physiology,* 82, 499–503.
3. Douglas, J. (2017). Physiological demands of eventing and performance related fitness in female horse riders. [Doctoral thesis]. University of Worcester, Worcester.
4. Fabritius, C., & Elovainio, R. (1978). Ratsastus tehokasta kuntourheilua. [Horseback riding is an effective fitness sport.] *Hippos,* 1, 6–9.
5. Fédération équestre internationale FEI. (n.d.). *FEI dressage.* https://www.fei.org/dressage
6. Fédération équestre internationale FEI. (n.d.). *FEI eventing.* https://www.fei.org/eventing
7. Fédération équestre internationale FEI. (n.d.). *FEI eventing rules.* https://inside.fei.org/fei/disc/eventing/rules
8. Fédération équestre internationale FEI. (n.d.). *FEI jumping.* https://www.fei.org/jumping
9. Fédération équestre internationale FEI. (n.d.). *FEI jumping rules.* https://inside.fei.org/fei/disc/jumping/rules

10. Geor, R. J., Hinchcliff, K. W., & Kaneps, A. J. (2008). *Equine exercise physiology: the science of exercise in the athletic horse.* Edinburgh: Saunders/Elsevier.
11. Gutierrez Rincón, J. A., Vives Turcó, J., Martinéz, M., & Vagué, C. I. (1992). A comparative study of the metabolic effort expended by horse riders during a jumping competition. *British Journal of Sports Medicine*, 26(1), 33–5.
12. Hitchens, P., Blizzard, L., Jones, G., Day, L. & Fell, J. (2011). Are physiological attributes of jockeys predictors of falls? A pilot study. *BMJ Open,* 1:e000142. doi:10.1136/bmjopen-2011- 000142
13. Hyttinen, A-M. (2015). Kestävyys- vs. voimaharjoittelun vaikutus esteratsastajan suorituskykyprofiiliin. [Effects of endurance vs. strength training on physical characteristics in female show–jumping riders.] [Master´s thesis]. University of Jyväskylä, Jyväskylä.
14. Hyttinen A-M., & Häkkinen, K. (2019). Physical fitness profile in female horseback riders. *The Journal of Sports Medicine and Physical Fitness* 59(12), 1944–50.
15. Ille, N., Aurich, C., Erber, R., Wulf, M., Palme, R., Aurich, J., & von Lewinski M. (2014). Physiologigal stress responses and horse rider interactions in horses ridden by male and female riders. *Comparative Exercise Physiology*, 10(2), 131–138.
16. Jeukendrup, A., & Van Diemen, A. (1998). Heart rate monitoring during training and competition in cyclists. *Journal of Sports Sciences,* 16, 91–99.
17. Meyers, M. (2006). Effect of equitation training on health and physical fitness of college females. *European Journal of Applied Physiology,* 98, 177–184.
18. Meyers, M., & Sterling, J. (2000) Physical, hematological, and exercise response of collegiate female equestrian athletes. *The Journal of Sports Medicine and Physical Fitnes*s, 40, 131–138.
19. Perciavelle, V., Di Corrado, D., Scuto, C., Perciavelle, V., & Coco, M. (2014). Attention and blood lactate levels in equestrians performing show jumping. *Perceptual and Motor Skills*, 118(3), 733–745.
20. European horse network. (n.d.). *Position Statements.* www.europeanhorsenetwork.eu/position–statements/
21. Roberts, M., Shearman, J., & Marlin, D. (2010). A Comparison of the Metabolic Cost of the Three Phases of the one–day event in female collegiate riders. *Comparative Exercise Physiology,* 6, 129–135.
22. Sainas, G., Melis, S., Corona, F., Loi, A., Ghiani, G., Milia, R., Tocco, F., Marongiu, E., & Crisafulli, A. (2016). Cardio–metabolic responses during horse riding at three different speeds. *European Journal of Applied Physiology*, 116, 1985–1992.
23. Terada, K., Mullineaux, D., Lanovaz, J. L., Kato, K. & Calyton, H. (2004). Electromyographic analysis of the rider's muscles at trot. *Equine and Comparative Exercise Physiology,* 1(03), 193-198.
24. Trainer4Skills Ltd. (2020). *Trainer4Riding® ANALYTICS.* (Version 1.0). [Mobile app]. Trainer4Skills Ltd. https://trainer4riding.fi/trainer4riding-analytics-mobile-application/
25. Westerling, D. (1983). A Study of Physical Demands in Riding. *European Journal of Applied Physiology,* 50, 373–382.
26. Williams, J., & Tabor, G. (2017). Rider impacts on equitation. *Applied Animal Behaviour Science*, 190, 28–42.

27. Wolframm, I. A., & Micklewright, D. (2009). Pre–competitive levels of arousal and self–confidence among elite and non–elite equestrian riders. *Comparatrive Exercise Physiology*, 5(3–4), 153–159.
28. Wright, R., & Peters, D. M. (2008). A heart rate analysis of the cardiovascular demands of elite level competitive polo. *International Journal of Performance Analysis in Sport,* 8, 78–81.

Table 1. Physical characteristics and riding background (Mean ± SD) of female horseback riders in the total group of participants and two groups separately.

Variable	All (N=42)	Show Jumping (n=16)	Eventing (n=26)
Age (yr)	29.0 ± 9.2	25.5 ± 9.2	31.2 ± 8.7
Height (cm)	168.3 ± 6.3	170.3 ± 5.8	167.0 ± 6.5
Body mass (kg)	68.1 ± 10.3	68.6 ± 10.2	67.8 ± 10.5
BMI (kg/m^2)	24.1 ± 3.6	23.7 ± 3.8	24.3 ± 3.6
Riding years	23.1 ± 8.5	21.6 ± 8.4	24.0 ± 8.6
Competition years	15.2 ± 8.0	13.5 ± 8.6	16.2 ± 7.6
Level of Show Jumping (cm)	108.6 ± 9.0	110.6 ± 10.5	107.3 ± 7.9

BMI=Body Mass Index

Table 2. Mean oxygen uptake characteristics (Mean ± SD) during the obstacle test track in female horseback riders.

Variable	All (N=42)	Show Jumping (n=16)	Eventing (n=26)
Total time of OTT (min/s)	2.32 ± 0.2	2.36 ± 0.3	2.29 ± 0.2
• Round 1 (min/s)	1.13 ± 0.2	1.14 ± 0.2	1.14 ± 1.5
• Round 2 (min/s)	1.18 ± 0.2	1.20 ± 0.2	1.16 ± 2.0
VO_2^{riding}peak during total OTT (ml/kg/min)	34.4 ± 5.0	33.9 ± 4.4	34.7 ± 5.5
• Round 1 (ml/kg/min)	31.3 ± 4.8	31.4 ± 5.0	31.2 ± 4.8
• Round 2 (ml/kg/min)	34.3 ± 5.1	33.5 ± 4.6	34.7 ± 5.5
VO_2^{riding}mean during total OTT (ml/kg/min)	26.4 ± 4.0	25.9 ± 3.6	26.7 ± 4.2
• Round 1 (ml/kg/min)	22.9 ± 4.0	22.4 ± 4.0	23.2 ± 4.0
• Round 2 (ml/kg/min)	29.5 ± 4.2	29.2 ± 3.4	29.8 ± 4.7

OTT=obstacle test track

Table 3. Mean heart rate and blood lactate characteristics (Mean ± SD) in the obstacle test track in female horseback riders.

Variable	All (N=42)	Show Jumping (n=16)	Eventing (n=26)
HR^{riding}peak during total OTT (bpm)	185.0 ± 9.6	187.5 ± 7.6	183.4 ± 10.4
• Round 1 (bpm)	182.3 ± 9.7	184.8 ± 8.8	180.8 ± 10.1
• Round 2 (bpm)	184.9 ± 9.5	187.3 ± 7.6	183.4 ± 10.4
HR^{riding}mean during total OTT (bpm)	178.1 ± 10.2	180.6 ± 8.6	176.5 ± 10.9
• Round 1 (bpm)	172.9 ± 10.7	175.6 ± 9.6	171.3 ± 11.2
• Round 2 (bpm)	182.8 ± 10.0	185.3 ± 8.0	181.2 ± 10.9
Blood lactate max after total OTT (mmol/L)	7.6 ± 2.2	6.7 ± 1.7	8.1 ± 2.3

OTT=obstacle test track

Table 4. Obstacle test track analysis (Mean ± SD) at each obstacle (1-22) of female horseback riders and their horses in two groups of participants separately.

Variable	Show Jumping (n=16)			Eventing (n=26)		
Type and number of obstacle	Error points	HR rider (bpm)	HR horse (bpm)	Error points	HR rider (bpm)	HR horse (bpm)
Round 1						
1 Oxer	0	160 ± 12	138 ± 14	1	155 ± 14	134 ± 18
2 Vertical	2	167 ± 11	152 ± 13	5	163 ± 12	148 ± 15
3 Vertical	0	171 ± 11	157 ± 13	1	167 ± 12	152 ± 15
4 Oxer	1	177 ± 11	157 ± 17	2	172 ± 11	159 ± 14
5 Vertical	3	178 ± 10	164 ± 13	0	174 ± 11	160 ± 14
6 Vertical	1	181 ± 9	171 ± 13	3	176 ± 11	165 ± 14
7 Oxer	0	183 ± 9	173 ± 13	0	177 ± 11	167 ± 14
8 Oxer	0	183 ± 9	177 ± 14	0	179 ± 10	171 ± 12
9 Vertical	2	184 ± 9	177 ± 14	4	179 ± 10	172 ± 12
10 Vertical	5	184 ± 9	176 ± 17	2	180 ± 10	173 ± 13
11 Oxer	0	184 ± 8	174 ± 22	0	181 ± 10	173 ± 13
Total	14			18		
Mean		178 ± 8	166 ± 12		173 ± 8	162 ± 12
Round 2						
12 Oxer	1	185 ± 8	171 ± 23	0	181 ± 10	173 ± 13
13 Vertical	3	185 ± 8	169 ± 23	1	181 ± 11	170 ± 13
14 Vertical	1	185 ± 8	169 ± 22	2	181 ± 11	169 ± 14
15 Oxer	0	186 ± 8	168 ± 22	2	182 ± 11	169 ± 14
16 Vertical	3	186 ± 8	168 ± 19	5	182 ± 11	169 ± 14
17 Vertical	1	186 ± 8	172 ± 14	1	182 ± 11	171 ± 12
18 Oxer	0	186 ± 8	172 ± 14	0	182 ± 11	171 ± 12
19 Oxer	0	187 ± 8	170 ± 22	0	182 ± 11	171 ± 12
20 Vertical	2	187 ± 8	171 ± 22	1	183 ± 11	170 ± 13
21 Vertical	5	186 ± 7	176 ± 14	4	183 ± 11	169 ± 14
22 Oxer	0	187 ± 8	174 ± 14	2	182 ± 11	169 ± 13
Total	16			18		
Mean		186 ± 1	171 ± 3		182 ± 1	170 ± 1

1 error point = 4 faults (refusal, circle or fault), Vertical = a straight, upright fence where all the poles are in the same vertical plane. Oxer = a spread fence where both the front and back poles set at the same height.

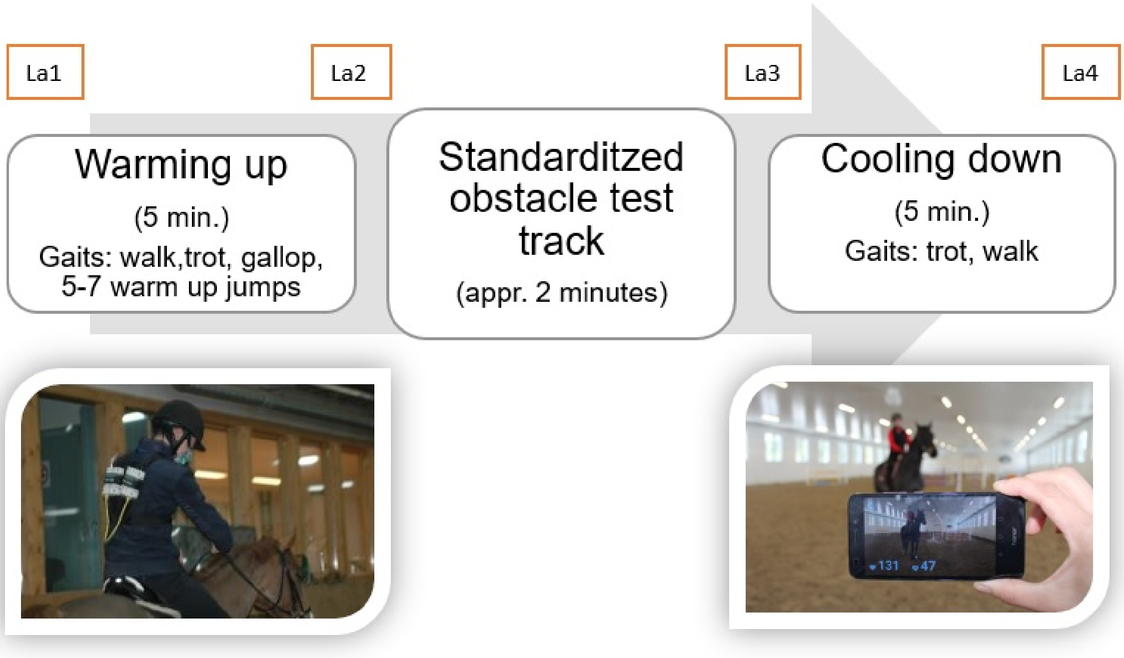

Figure 1. The experimental design of the riding track. Blood lactate measurement points are marked by La1-La4 (Lactate 1, Lactate 2 etc.) The oxygen uptake measuring instrument is showed in the photo on the left. Heart rate and video synchronization measuring technology is shown in the photo on the right.

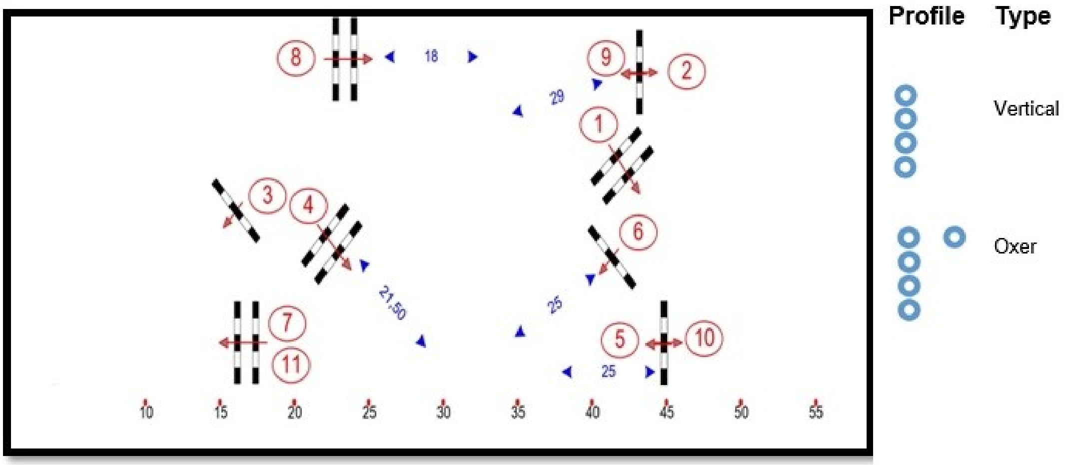

Figure 2. Obstacle test track (1-11) with profiles and types of obstacles. The distances between obstacles are indicated in meters.

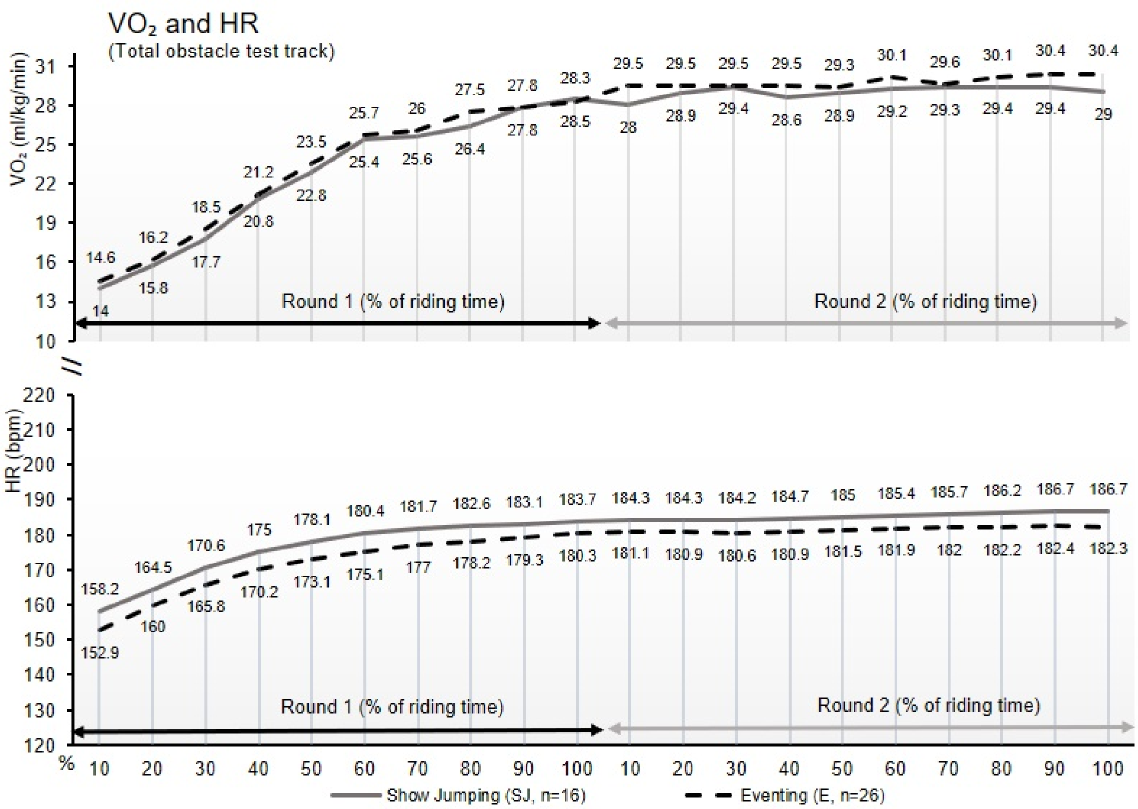

Figure 3. Oxygen uptake and heart rate levels during the obstacle test track (round 1 and round 2) in two groups of participants.