Cardiac arrhythmias in clinically healthy showjumping horses

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Summary

Reasons for performing study: Electrocardiographic reference values of clinically normal horses during exercise are a prerequisite when evaluating horses with poor performance or horses presented with cardiac abnormalities (e.g. valvular regurgitation). No published studies have reported cardiac rhythms of clinically normal showjumping horses.

Objectives: To demonstrate the feasibility of obtaining exercise electrocardiogram (ECG) in normal horses during showjumping and also to document the prevalence and frequency of arrhythmias in association with exercise.

Methods: Thirty-four healthy showjumping horses aged 4–13 years (mean 7.5 years) underwent clinical examination and resting echocardiography. Modified chest lead ECG examinations were performed during rest, during a standardised showjumping course, as well as for the following 45 min recovery. All ECG recordings were analysed for presence and frequency of arrhythmias.

Results: Six horses (17%) were excluded due to ECG recordings of poor diagnostic quality. Echocardiography demonstrated that 11 (39%) horses had one or more mild or moderate valvular regurgitations, but no associations were found between valvular regurgitation and arrhythmias. Supraventricular premature complexes (SVPCs) were found in 9 (32%) horses at rest, 25 (89%) during exercise and 15 (54%) during recovery. Only few arrhythmias occurred in each horse (<9 SVPCs/horse); however, one horse had 13 single SVPCs during exercise and another developed 41 SVPCs during recovery. SVPCs occurred typically at low HR (40–98 beats/min). Ventricular premature complexes (VPCs) was demonstrated in 5 (18%) horses during exercise and 2 (7%) during recovery, with <2 VPCs/horse.

Conclusions: It is possible to obtain good quality ECG during showjumping. Reference values for normal performing showjumping horses are presented for the first time and showed a high prevalence of SVPCs both during and after exercise, but few VPCs.

Potential relevance: Normal reference values enable future studies of cardiac function in showjumping horses presented with poor performance and provide valuable information for veterinary practitioners in the field.

Introduction

Few investigations have been published on the cardiac rhythm of clinically normal horses during exercise (Scheffer et al. 1995; Ryan et al. 2005). Reference values from clinically normal performing horses are a prerequisite for evaluation of deviant findings and the influence on athletic performance of the horse. Most previous studies have either focused on horses with poor performance (Martin et al. 2000; Jose-Cunilleras et al. 2006) or included small numbers of horses (Raekallio 1992; Scheffer et al. 1995). In showjumping horses, only heart rate (HR) has been investigated (Art et al. 1990; Lekeux et al. 1991; Covalesky et al. 1992; Barrey and Valette 1993; Sloet van Oldruitenborgh-Oosterbaan et al. 2006). The value of electrocardiography (ECG) of horses at rest is limited because cardiac diseases and disturbances in cardiac rhythm, leading to decreased performance, only rarely manifest themselves during rest (Young 2007). Furthermore, some cardiac arrhythmias tend to appear in the recovery period after exercise (Reef 1999a). Due to lack of literature describing cardiac rhythm in horses during exercise, the clinical significance of some arrhythmias is not well established (Jose-Cunilleras et al. 2006). For example, the most recent guidelines suggested premature depolarisations to be clinically important if more than 2 premature depolarisations were seen during peak exercise, or if multiple (>5) pairs or paroxysms of premature depolarisations were detected during or immediately after peak exercise (Martin et al. 2000). However, the validity of these cut-off values has been questioned (Jose-Cunilleras et al. 2006), because specific numbers of premature depolarisations were found to exceed those values in a significant proportion of racehorses in training, in the absence of known performance limitations (Ryan et al. 2005). In addition, no standardised guidelines describe how to consistently diagnose various arrhythmias. Of utmost importance is a definition of premature complexes, which is currently lacking. Recently, a study in Standardbred Trotters described guidelines for definitions of premature complexes (Nørgaard et al. 2008).

The aim of this study was to demonstrate the feasibility of obtaining exercise ECG in clinically normal horses during showjumping, and also to document the prevalence and frequency of arrhythmias in association with this type of exercise and subsequent recovery.
Materials and methods

Selection of horses

Horses were included from 2 different yards located in Denmark. In all cases professional trainers considered the horses to be well performing and horses had been in regular training for at least 4 weeks prior to the study. Physical examinations including temperature, auscultation of heart and lungs were made of each horse before ECG application and any abnormalities were registered. Horses were included with a normal clinical examination and with murmurs <IV/VI and no pathological arrhythmias during auscultation or resting ECG. ECG (2D guided M-Mode and colour flow Doppler) was performed using a ultrasound machine with a 1.5 mHz phased array probe with harmonic imaging by one operator (R.B.) to assess heart size and valvular insufficiencies as previously described (Buhl et al. 2004). For tricuspid and mitral valvar regurgitation, the area of the regurgitant jet in comparison with the approximated size of the atrium was used to categorise the size of the regurgitation. A very small jet occupying <10% of the area of the atrium was classified as mild regurgitation (Buhl et al. 2004). For aortic regurgitation, maximal diameter of the regurgitation just below the aortic valve was measured. The diameter of the jet in comparison with the diameter of the left ventricular outflow tract (LVOT) was used to categorise the size of aortic regurgitation (Willems et al. 1997). We defined mild regurgitation as the maximal diameter of the regurgitant jet relative to LVOT being less than one-third. A moderate aortic regurgitation was defined as the relation between the maximal diameter of the regurgitant jet relative to LVOT being between one-third to one-half. Due to logistics, the ultrasound examination was performed either before exercise ECG examination or within 2 weeks after the ECG examination. The operator was blinded to the electrocardiographic results obtained in the horses.

Study population

The study population consisted of 34 clinically normal showjumping horses. Six horses (17.6%) were excluded from the study population, due to poor quality exercise ECG recordings, while 28 horses (18 from one yard and 10 from the other) completed the study. Mean age was 7.5 years (range 4–13) and the group comprised 10 mares, 14 geldings and 4 stallions. Due to differences in age and training stage, the horses were competing 3 defined showjumping levels; 120 cm (n = 14), 140 cm (n = 10) and 160 cm (n = 4). The breeds of horses were Danish Warmblood (n = 19), Belgian Warmblood (n = 1), German Oldenburger (n = 3), Oldenburger (n = 1), Brandenburger (n = 1) and Holsteiner (n = 3).

ECG equipment and recording method

A modified base-apex lead was applied, which enables the horse to be ridden with saddle (Gatti and Holmes 1990; Young 2007). Two self adhesive ECG electrodes were placed beneath each other at the left shoulder, in front of the saddle and 2 electrodes were placed in the same manner, just left to the ventral midline, behind the girth. Adhesive foam tape was used as an extra safety to secure the electrodes. An ECG unit (Kruetch Televet) was connected to the electrodes and fixed in front of the saddle. The ECG recordings were stored on a SD card for later reviewing on computer. In addition to cardiac rhythm, changes in HR were also registered.

The ECG recordings were made during showjumping training, in the horses’ usual surroundings. Recordings were made during 3 different periods: 5 min at rest followed by exercise and finished after the following 45 min recovery. As the activity level around the horses in the stables was high during the study period, a true resting HR could not be obtained. Horses were ridden by their usual riders and all underwent the same training programme in an indoor arena. This consisted of 15 min of warm-up, changing between walk, trot and canter, followed by individual warm-up jumps (10–20 jumps), with walk between jumps and finally a showjumping course, consisting of 10–12 successive obstacles. The duration to complete the course was approximately 2 min and it was ridden with a speed of approximately 350 m/min. Events during exercise, such as gait or pace transitions, excitement or when the horse forced a jump, were noted against time in case records. This was used in the following ECG analysis as possible explanations of arrhythmias. Within 2 min after finishing showjumping the horses were taken to the stable and ECG recording continued for 45 min. Mean HR was calculated at 2, 5, 15, 30 and 45 min post exercise.

ECG analysis

The ECG recordings were subjected to a rhythm analysis by the integrated program. It included R peak markings and measurement of R-R intervals. The R peak was considered to be irregular if the recent R-R interval deviated by more than the ‘maximum deviation’ percentage from the preceding R-R interval. In this study, a R-R interval deviation of 20% was chosen, as the maximum accepted deviation in horses during rest and recovery. During exercise, an R-R interval deviation of 10% was chosen as maximum (Nørgaard et al. 2008). In addition, the ECG recordings were manually analysed, to discover arrhythmias not registered by the software or artefacts falsely registered as arrhythmias. The arrhythmias, found in this study, were defined as follows:

- Sinoatrial block (SA block): absence of P waves for a duration of twice the previous P-P interval (Bonagura and Miller 1985).
- Sinus pause: >20% (during rest) or 10% (during exercise) increase of the distance between 2 R waves (Garcia and Miller 2004; Ulfberg and Clark 2006).
- Sinus arrhythmia: variable R-R intervals, where the heart slows for a few beats, speeds up and slows again, until a more stable rhythm is established (Menzies-Gow 2001).
- Second degree AV Block: P wave not associated with any following QRS complex and double length of R-R interval (Bonagura and Miller 1985).
- Supraventricular premature complex (SVPC): R-R interval decreased >20% (during rest) or 10% (during exercise) in distance from the previous R-R interval and no change in configuration of the QRS complex (Nørgaard et al. 2008).
- Supraventricular tachycardia (SVT): a series of more than 3 consecutive SVPCs
- Ventricular premature complex (VPC): R-R interval decreased >20% (during rest) or 10% (during exercise) in distance from the previous R-R interval and configuration of QRS complex was of obviously abnormal morphology than the previous sinus QRS complex (Reimer et al. 1992; Nørgaard et al. 2008).
Arrhythmias in showjumping horses

Statistical analysis

Descriptive analysis of arrhythmias included calculation of prevalence, frequency of arrhythmias, mean ± s.d. and 95% confidence intervals. Analytical statistics consisted of a 2-sided analysis of variance (ANOVA), with arrhythmias and periods (rest, exercise, recovery) defined as categorical variables and random effect of horses. Estimates and coupled comparisons were computed by ‘The Mixed Procedure’; ‘Type 3 Tests of Fixed Effects’ and ‘Differences of Least Squares Means’ using Statistical Analysis Software Version 9.1'. Results were interpreted on the 5% significance level.

Results

Clinical examination

Rectal temperature, respiratory rate and pulmonary auscultation were within normal reference values. Cardiac auscultation was unremarkable. Clinical examinations of all the horses fell within the inclusion criteria of the study and were unremarkable with resting HR within normal reference values, cardiac rhythm was normal and no murmurs auscultated, except in 2 horses that had a Grade 3 holodiastolic murmur with a PMI over the aortic valve area. Since murmurs of Grade 3 or less were acceptable according to the inclusion criteria of the study, these horses were not excluded.

Quality of ECG recordings

The quality of the ECG was considered acceptable if distinct R waves were detected during the recordings. We accepted minor deviation on the base line as well as minor changes in amplitude as long as the R waves were identifiable. For the 28 horses completing the study, distinct R waves were identifiable and the quality of the ECG was accepted.

Echocardiography

All horses except one (the horse was sold after the exercise ECG examination and before echocardiographic examination) underwent echocardiographic examination, and no abnormal enlargement of the size of left ventricle or abnormal contractility of the left ventricle was observed. Eleven of the horses (39%) had one or more mild or moderate cardiac valvular regurgitations (mitral valvular regurgitation, mild degree: n = 2, tricuspid valvular regurgitation, mild degree: n = 2, aortic valvular regurgitation, mild degree: n = 7, aortic valvular regurgitation, moderate degree: n = 2). No significant correlation was found between valvular regurgitation and arrhythmias during rest, exercise or recovery.

Heart rate

Minimum and maximum HR values are shown in Figure 1 for the different time periods (rest, warm-up exercise and showjumping course). During the showjumping, the mean maximal HR increased to 180 beats/min. The maximum HR at rest was extremely high due to one very excited horse. The mean HR values for the recovery period are indicated at different time points. At 30–45 min within the recovery period, the total number of horses was reduced to 26, because some of the recordings were ended prematurely.

Fig 1: Mean heart rate values calculated for the 3 time periods: rest, warm-up exercise, showjumping course and 2, 5, 15, 30 and 45 min within the recovery period. Intervals of minimum and maximum heart rate values, for each time period rest, warm-up exercise and showjumping course are shown. Error bars indicate 95% confidence intervals of the mean.

Prevalence and frequency of arrhythmias

Figure 2 shows examples of sinus pause, SVPC and VPC. The prevalence and distribution of horses developing arrhythmias during rest, exercise and recovery are shown in Table 1. For 2 horses, high numbers of second degree AV blocks were found during recovery, with 70 and 48 s degree AV blocks, respectively. Both horses had also second degree AV blocks at rest but in lower number. The prevalence and distribution of SVPCs and VPCs for the individual horses are shown in Table 2. The frequency of SVPCs during either exercise or recovery was 9 SVPCs/horse, except one horse showing 13 single SVPCs during exercise and another 41 SVPCs during recovery. SVPCs occurred typically during the warm-up exercise where the horses were at walk or trot with a HR range 40–98 beats/min and the HR was decreasing. The VPCs during exercise occurred at HR range 120–160 beats/min at a stable HR. Five horses experienced couples and/or triplets of SVPCs.

The analysis of variance included sinus pause, second degree AV block and SVPC. Other types of arrhythmia were left out, because of too few observations. A significant interaction existed between arrhythmia and period (rest, exercise, recovery) (P = 0.0302) meaning that types of arrhythmia changed from one period to another. During exercise significant proportion of sinus pauses and SVPCs occurred (P = 0.0003 and P = 0.0006, respectively), while significantly more SVPCs and second degree AV blocks occurred during recovery (P = 0.0086 and P<0.0001, respectively).

Discussion

This study is the first to demonstrate that it is possible to obtain high quality ECG recordings during showjumping in a majority of horses. A minority of ECGs were excluded due to poor diagnostic quality but no obvious explanation was found. However, we did not
clip the horses before placing the electrodes, which may have increased the contact between skin and electrodes resulting in higher ECG quality.

Showjumping horses are exercised differently in comparison to racehorses as HR during both warm-up and jumping is much more labile with large fluctuations following frequent gait and pace transitions and horses are exercised at much lower HR as seen in Figure 1. The highest HR values of horses in the present study were reached by completion of the showjumping course, where a progressive rise in HR occurred, to an average of 180 beats/min. This is in agreement with previous studies of HR in showjumping horses (Art et al. 1990; Lekeux et al. 1991; Sloet van Oldruitenborgh-Oosterbaan et al. 2006). On the other hand, HR during training and racing in racehorses are much more stable where training aims towards a linear increase in HR to submaximal or maximal level at 200–240 beats/min (Martin et al. 2000; Ryan et al. 2005). These differences in training methodology may explain the high prevalence of arrhythmias in the present study. An interesting result of the present study was the high prevalence of SVPCs during warm-up where large fluctuations occur as the horses’ pace changes. During showjumping, the prevalence of arrhythmias was low. It is well known that horses exhibit high vagal tone and it is believed that fluctuations on autonomic tone are related to arrhythmias (Patteson 1999; Reef 1999b; Physick-Sheard et al. 2000). In a recent study, it was observed that the autonomic control was reduced during high exercise intensity (Cottin et al. 2005), which supports the results of the present study where arrhythmias primarily occurred when HR decreased probably influenced by the parasympathetic nervous system.

The prevalence of horses with SVPCs was higher during exercise in the present study, compared to other studies in clinically healthy racehorses (Ryan et al. 2005; Lindholm et al. 2008). In agreement with Ryan et al. (2005) the majority of SVPCs occurred during the warm-up phase at relatively low HR and not at peak exercise. The frequency of SVPCs per horse was, however, lower in the present study than in other studies (Martin et al. 2000; Ryan et al. 2005; Jose-Cunilleras et al. 2006). It is interesting that no SVPCs were observed directly in connection with jumping, but most arrhythmias occurred in between jumps when HR decreased. A likely explanation may be the large fluctuation in HR and influence of autonomic nervous system in showjumping horses during exercise as described above.

Ventricular premature beats (VPCs) are the result of abnormal electrical activity originating in the ventricles resulting in premature contractions (Bonagura and Miller 1985). The significance of VPCs is debatable and generally they are considered indicative of myocardial disease (Reimer et al. 1992). The VPCs observed during exercise in the present study occurred at higher HR (range 120–160 beats/min) in comparison to SVPCs (HR range 40–98 beats/min). Although no VPCs occurred while the horses were actually jumping, no decrease or changes in HR was observed in relation to the occurrence of the VPCs as observed for the SVPCs. Current guidelines recommend that >2 SVPCs or VPCs during peak exercise or >5 pairs during the recovery period should be significant findings.

**TABLE 1: Prevalence (n, %) of cardiac arrhythmias during rest, exercise and recovery period**

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<tr>
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<th>Sinus pause</th>
<th>Sinus arrhythmia</th>
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<th>SVPC</th>
<th>VPC</th>
<th>Sinus tachycardia</th>
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<td>Rest</td>
<td>3 (10.7)</td>
<td>7 (25.0)</td>
<td>8 (28.6)</td>
<td>9 (32.1)</td>
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<td>25 (89.3)</td>
<td>23 (82.1)</td>
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<td>25 (89.3)</td>
<td>5 (17.9)</td>
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<td>Recovery</td>
<td>19 (67.9)</td>
<td>11 (39.3)</td>
<td>6 (21.4)</td>
<td>15 (53.6)</td>
<td>2 (7.1)</td>
<td>1 (3.6)</td>
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Fig 2: ECG recorded during exercise in 3 showjumping horses. a) a sinus pause (arrow), b) supraventricular premature beat (SVPC) (arrow); and c) a ventricular premature beat (VPC) (arrow). The numbers below indicate HR for each R-R interval.
Arrhythmias in showjumping horses

for possible performance reduction (Martin et al. 2000) but these cut off values have been questioned recently as too many clinically normal horses exceed these numbers of SVPCs and VPCs during exercise or recovery (Ryan et al. 2005). In the present study, only one SVPCs and 2 VPCs were observed during showjumping, which for these horses is considered peak exercise, whereas the majority of SVPCs occurred during warm-up at nonpeak exercise, which is in agreement with the previous study (Ryan et al. 2005). As mentioned previously, the changes in physical intensity during exercise while showjumping and the fact that showjumping horses are different breed in comparison to racehorses makes it difficult to compare with studies involving horses with severe valvular regurgitations or horses presenting with poor performance. Future exercise ECG studies involving horses with severe valvular regurgitations or

TABLE 2: Total number of SVPCs and VPCs during rest, warm-up exercise, showjumping course and recovery for each of the 28 horses completing the study. If double or triple SVPCs were found this is specified in brackets

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<td>27</td>
<td>10</td>
<td>M</td>
<td>DV</td>
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<td>28</td>
<td>10</td>
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G = gelding, M = mare, S = stallion. DV = Danish Warmblood, O = Oldenburger, GO = German Oldenburger, BW = Belgian Warmblood, B = Brandenburger, H = Holsteiner.

Existing guidelines for assessments of arrhythmias are descriptive and, to some extent, subjective and a standardised protocol of definition of arrhythmia during exercise has been lacking (Martin et al. 2000; Ryan et al. 2005; Jose-Cunilleras et al. 2006). In heart rhythm analysis of this study we aimed to standardise the arrhythmia criteria by choosing the 'maximum deviation' percentage of R-R intervals. This was based on earlier study of standard criteria for arrhythmia assessment, where it was shown that for HR of 60–90 beats/min, the normal variation of R-R intervals is up to 10%; at 90–180 beats/min, it varies 5% and at 180–250 beats/min the R-R interval variation is up to 10% (Nørgaard et al. 2008). By establishing fixed variation of R-R interval the subjective assessment is minimised and the variability between and within readings will decrease.

In conclusion, we found it possible in practice to obtain good quality ECG recordings in a majority of horses investigated during showjumping. No arrhythmias or appreciable artifacts were associated with jumping. A high prevalence of horses developed SVPCs, sinus pauses and sinus arrhythmia during warm-up exercise but these were rare during showjumping. VPCs were seen in fewer horses and appeared <2/horse. Reference values of arrhythmias for normally performing showjumping horses are presented for the first time, which contributes to the knowledge of cardiac rhythm in horses during and after exercise. Knowledge of the occurrence of arrhythmias in well-performing horses is essential for equine veterinarians when evaluating showjumping horses presenting with poor performance. Future exercise ECG studies involving horses with severe valvular regurgitations or

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cardiac hypertrophy are necessary to understand how cardiac pathology influences the electrocardiographic conduction system during increased physical demands. Additionally, future validation studies are indicated including inter- and intraobserver variation as well as day-to-day variation within horses.

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Conflict of interest

The authors declare no conflicts.

Manufacturers’ addresses

1Vivid i, GE Healthcare, Brøndby, Denmark.
2Kruuse A/S, Langeskov, Denmark.
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4Kruuse A/S, Langeskov, Denmark.
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