Cardiovascular Evaluation in Sport Horses using Elerctrocardiography, Blood Pressure and Cardiac Troponin T

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Abstract
The continuous development of equestrian sports in Romania has increased interest in the medical monitoring of horses involved in competitive activities. In this context, the warmblood population represents one of the main genetic resources used in show jumping and other equestrian disciplines. Repeated physical exertion induces physiological cardiovascular adaptations; however, in certain individuals it may also promote transient functional disturbances or processes of myocardial overload. The present study aimed to provide an integrated evaluation of the cardiovascular response to exercise through electrocardiography, arterial blood pressure assessment, and cardiac troponin T measurement. Six adult sport horse individuals were examined at rest, immediately after a standardized exercise protocol, and after 10 minutes of recovery. The results revealed post-exercise sinus tachycardia, variable heart rate recovery, marked increases in systolic blood pressure, and mild changes in the amplitude of electrocardiographic complexes. Cardiac troponin T increased from 2.818 pg/mL before exercise to 3.062 pg/mL after exercise, without statistical significance ($p>0.05$). These findings highlight the value of integrated cardiovascular monitoring for the assessment of exercise adaptation and the early identification of exercise-associated cardiovascular stress in Sport Horses.

Keywords: warmblood horse, equine cardiology, exercise training management.

1. Introduction

Over the last decades, equine sports medicine has undergone significant development, driven by the intensification of competitive equestrian activities and the increasing biological, economic, and athletic value of horses used in training and competition.
In this context, cardiovascular assessment has become a fundamental component of preventive medicine and performance management, considering the essential role of the heart in the adaptation of the organism to intense and repetitive physical effort.
The expansion of equestrian sports in Romania has increased the interest in monitoring the physiological status and exercise capacity of performance horses. In the past, horses were used predominantly for traction and utilitarian purposes, while their involvement in sporting and recreational activities was limited. Consequently, systematic monitoring of health status, particularly cardiovascular function, was not commonly integrated into the medical management of this species.
In Romania, the development of the equestrian sector and the increasing use of Sport Horses in show jumping competitions require the implementation of modern clinical and

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paraclinical evaluation protocols. Although these animals exhibit high athletic capacity, repetitive physical effort may favor the occurrence of rhythm disturbances, transient hemodynamic changes, or increases in cardiac biomarkers suggestive of myocardial stress.

Electrocardiography represents the principal method for the evaluation of cardiac rhythm in horses. Hesselkilde et al. [1] described a modern approach for obtaining 12-lead electrocardiograms in horses, adapted to the anatomical particularities of the species, demonstrating that this technique provides more stable recordings and improves clinical interpretation.

Arrhythmias and cardiovascular abnormalities in equine athletes require careful clinical interpretation because of their potential effects on exercise tolerance, athletic performance, and competition safety [2]. From a biochemical perspective, cardiac troponin I is considered a sensitive biomarker of myocardial injury.

Short-duration maximal exercise may induce transient increases in cardiac troponin I concentrations even in clinically healthy horses [3] Cardiac troponin I values should be interpreted in relation to training intensity and competition status in racing horses [4]. In addition, endurance exercise has been associated with increased plasma concentrations of cardiac troponin I, supporting the usefulness of this biomarker in monitoring the myocardial response to exercise in horses [5].

Therefore, the aim of the present study was to perform an integrated evaluation of electrocardiographic, hemodynamic, and biochemical changes in Sport Horses under three distinct physiological conditions: at rest, immediately after exercise, and following a short recovery period.

2. Materials and methods

Study design and animals included

The study was conducted in a private equine facility located in Sânandrei, Timiș County, Romania, and had a prospective observational design. The experimental group consisted of six Romanian Sport Horses, including four mares and two stallions, aged between 8 and 16 years. All animals were actively involved in show jumping training and were considered clinically healthy at the time of inclusion in the study.

Housing and management conditions

The horses were maintained under permanent stabling conditions in individual stalls. The stable was divided into two functional compartments: the first included six standing stalls and five boxes, while the second contained two additional boxes. The animals included in the study were housed in boxes with an approximate surface area of 14 m², equipped with concrete flooring and straw bedding, ensuring adequate welfare conditions. Feeding and watering were performed according to the routine management protocol of the facility, without modifications during the experimental period.

Exercise protocol

Cardiovascular assessment was performed under three distinct physiological conditions: at rest, immediately after exercise, and after a 10-minute recovery period. The exercise protocol was conducted on the facility training ground and consisted of lunging exercises lasting approximately 30–40 minutes, including 10 minutes of walking, 15 minutes of trotting, and 5 minutes of galloping. This protocol was designed to reproduce routine training conditions and to induce a progressive cardiovascular response.

Electrocardiographic recordings

Electrocardiographic evaluation was performed using 12-lead digital electrocardiographs (Cardioline Delta 1 and Contec 300 GA) equipped with an 80 mm thermal paper printing system. Electrocardiograms were recorded with the animals in a quadrupedal standing position using the base–apex lead configuration (Dubois), a standard method for equine electrocardiographic examination. For each horse, electrocardiographic recordings were obtained at rest, immediately after exercise, and after a 10-minute recovery period. The analyzed parameters included heart rate, cardiac rhythm, and possible conduction or repolarization abnormalities.

Blood sample collection and biochemical analysis

For biochemical assessment, venous blood samples were collected from the jugular vein both at rest and according to the experimental time points. The puncture site was prepared by rigorous local antisepsis using an iodine-based solution (Betadine).

Samples were collected into vacutainer tubes without anticoagulant, as well as into tubes containing separator gel and clot activator intended for biochemical analyses. Cardiac troponin (cTn) determination was performed in a specialized laboratory (Bioclinica) according to standard laboratory protocols.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics software (version 23). The analysis included descriptive statistics and paired Student's t-test for evaluating differences between the experimental stages investigated, with statistical significance set at $p<0.05$.

3. Results and discussion

The integrated analysis of cardiovascular function in Romanian Sport Horses revealed electrophysiological and hemodynamic variations dependent on the functional state of the animals, namely rest, post-exercise, and recovery. The interpretation of these changes was correlated with electrocardiographic, blood pressure, and biochemical parameters to assess cardiovascular adaptation to exercise.

Under resting conditions, the electrocardiograms revealed a regular sinus rhythm, with heart rate values remaining within the physiological limits characteristic of the equine species. The electrocardiographic tracings are presented in Figure 1, while the corresponding parameters are summarized in Table 1. No pathological alterations were identified in the duration or amplitude of the P, QRS, and T waves, nor in the PQ, QT, and ST segments and intervals, all values remaining within physiological limits.

These findings are consistent with previous observations emphasizing the predominant role of vagal tone in maintaining low heart rate values in clinically healthy horses [6].

Well-defined atrioventricular complexes with increased QRS amplitude were observed, a feature commonly described in trained horses. The interpretation of equine electrocardiography primarily relies on the duration and amplitude of electrocardiographic complexes because of the absence of strict standardization of lead placement in this species [7]. Increased QRS voltage may also reflect adaptive myocardial remodeling associated with repeated physical exercise [8].

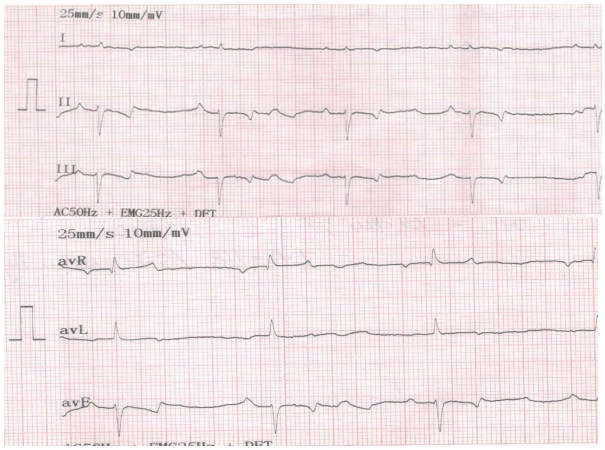

Figure 1. Electrocardiogram recorded in the horse at rest (25 mm/s, 10 mm = 1 mV)

Table 1. Values of electrocardiographic parameters recorded in the horse under resting conditions

ECG Parameters	Duration (s)	Amplitude(mV)
Unda P	0.08	0.2
P-R $(P-Q)_{int.}$	0.26	-
QRS	0.08	1
$Q-T_{int.}$	0.36	-
$ST_{segm.}$	-	izoelectric
$T-Q_{int.}$	0.92	-
$R-R_{int.}$	1.28	-

The presence of the U wave identified in certain resting electrocardiographic recordings was interpreted as a physiological phenomenon associated with delayed ventricular repolarization, without pathological significance in the analyzed clinical context. Similar findings reported in equine electrophysiology studies demonstrated that repolarization variability is strongly influenced by autonomic regulation [9].

In order to evaluate cardiovascular adaptation to exercise, functional electrocardiographic indices were calculated. The ventricular systolic index (VSI = 31%) remained within the physiological interval reported in the literature (20–50%), suggesting adequate morphofunctional cardiac capacity in relation to physical demand. However, the positioning of this value toward the upper physiological limit indicates the need for careful monitoring of cardiovascular adaptability to exercise. The atrial systolic index (ASI = 18%) and the diastolic-systolic coefficient (DSC = 2.5) suggested a relatively shortened diastolic period, which may negatively influence ventricular filling,

preload, and stroke volume during increased physical demand.

Immediately after exercise, the electrocardiographic tracings presented in Figure 2, together with the parameters summarized in Table 2, revealed sinus tachycardia, with heart rate increasing to approximately 60–80 bpm. This modification represents a physiological adaptive response to sympathetic stimulation and increased tissue oxygen demand induced by exercise. The electrocardiographic examination also demonstrated that the amplitude of the ventricular QRS complex in the unipolar aVF lead was higher than that recorded in the bipolar lead I, suggesting a vertically oriented heart positioned at approximately 90°, while the electrical cardiac axis maintained an intermediate orientation.

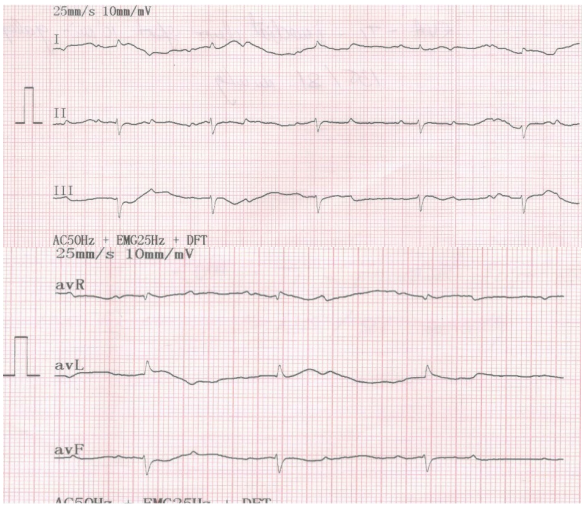

Figure 2. Electrocardiogram recorded in the horse after exercise (25 mm/s, 10 mm = 1 mV)

Table 2. Values of electrocardiographic parameters recorded in the horse after exercise

ECG Parameters	Duration (s)	Amplitude (mV)
Unda P	0.06	0.15
P-R (P-Q)$_{int.}$	0.2	-
QRS	0.06	0.35
Q-T$_{int.}$	0.4	-
ST$_{segm.}$	-	izoelectric
T-Q$_{int.}$	0.8	-
R-R$_{int.}$	1.08	-

Electrocardiograms recorded immediately after completion of the exercise protocol revealed sinus tachycardia, with heart rate increasing to approximately 60 bpm, with heart rate increasing to approximately 60 bpm. This finding represents a physiological adaptive response to exercise associated with sympathetic stimulation and increased tissue metabolic demand. The electrocardiographic tracings also showed a higher amplitude of the ventricular QRS complex in the unipolar aVF lead compared with the bipolar lead I (QRS DI<QRS aVF), suggesting a vertically oriented heart positioned at approximately 90°, while the electrical cardiac axis maintained an intermediate orientation.

Post-exercise recordings demonstrated reduced amplitudes of the atrioventricular complexes, particularly of the QRS complex, together with slight shortening of the T–Q interval corresponding to the general diastolic phase. These modifications may reflect shortening of diastolic duration, reduced ventricular filling, and decreased intraventricular blood volume secondary to physical exertion. Functional electrocardiographic indices showed that the ventricular systolic index (VSI) increased to 51%, exceeding the physiological interval and suggesting increased cardiovascular workload and transient exercise-induced functional adaptation. In contrast, the atrial systolic index (ASI = 20%) and the diastolic-systolic coefficient (DSC = 1.7) indicated preservation of relatively efficient diastolic function. Similar exercise-induced reductions in diastolic duration and ventricular filling time have been described as characteristic cardiovascular adaptive responses in horses [9].

After the 10-minute recovery period, the electrocardiographic tracings presented in Figure 3 and the electrocardiographic parameters summarized in Table 3 demonstrated a return of heart rate values toward resting levels, decreasing from approximately 60 bpm immediately after exercise to approximately 40 bpm during recovery. A regular sinus rhythm and an intermediate electrical cardiac axis were maintained throughout the recovery period, findings suggestive of adequate autonomic regulation and favorable cardiovascular adaptation to training exercise.

During the recovery period, electrocardiographic recordings continued to show reduced amplitudes of the P wave and QRS complex compared with the resting tracings, suggesting incomplete restoration of ventricular filling and persistence of mild transient myocardial functional alterations. Although the duration of atrioventricular systole and diastole remained within the physiological limits described for the equine species, the

decrease in heart rate observed after the 10-minute recovery period was not associated with normalization of atrioventricular complex amplitudes, indicating delayed recovery of myocardial functional capacity.

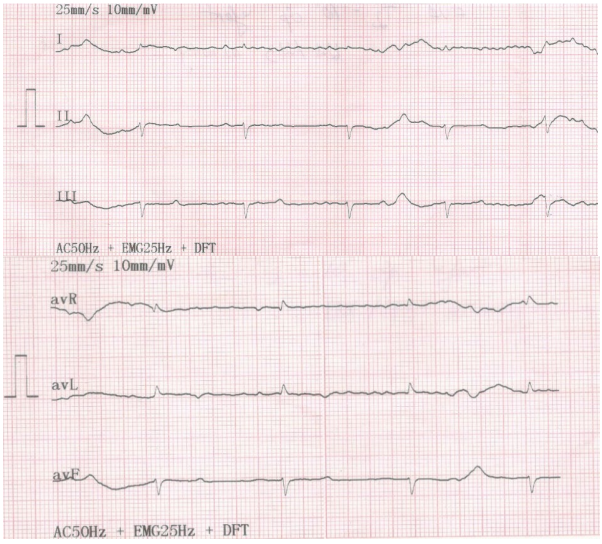

Figure 3. Electrocardiogram recorded in the horse after 10 minutes of recovery (25 mm/s, 10 mm = 1 mV)

Table 3. Values of electrocardiographic parameters recorded in the horse after 10 minutes of recovery

ECG Parameters	Duration (s)	Amplitude (mV)
Unda P	0.04	0.1
P-R (P-Q)$_{int.}$	0.16	-
QRS	0.04	0.3
Q-T$_{int.}$	0.4	-
ST$_{segm.}$	-	izoelectric
T-Q$_{int.}$	0.76	-
R-R$_{int.}$	1.16	-

Throughout all investigated stages—rest, post-exercise, and recovery—the ST segment remained isoelectric, without significant amplitude modifications, suggesting the absence of evident electrocardiographic signs of myocardial or subendocardial ischemia. However, electrocardiography has limited sensitivity in detecting myocardial ischemia in horses; therefore, electrocardiographic findings should be interpreted in correlation with cardiac biomarker assessment and additional cardiovascular investigations [10].

To evaluate cardiovascular adaptation during recovery, functional electrocardiographic indices were calculated. The ventricular systolic index (VSI = 40%) remained within the physiological interval reported in the literature (20–50%), supporting the presence of exercise-adapted morphofunctional cardiac capacity. In contrast, the atrial systolic index (ASI = 20%) and the diastolic-systolic coefficient (DSC = 1.6) continued to indicate a relatively shortened diastolic period, potentially affecting ventricular filling efficiency and preload. The persistence of these functional changes may contribute to reduced cardiovascular hemodynamic efficiency during recovery.

Considering the relationship between increased blood pressure and the development of cardiac remodeling processes, particularly myocardial hypertrophy, oscillometric blood pressure monitoring was performed during the three investigated experimental stages: rest, post-exercise, and recovery (Figure 4). The mean values recorded were 155/57 mmHg at rest, 175/81 mmHg immediately after exercise, and 165/73 mmHg after the 10-minute recovery period.

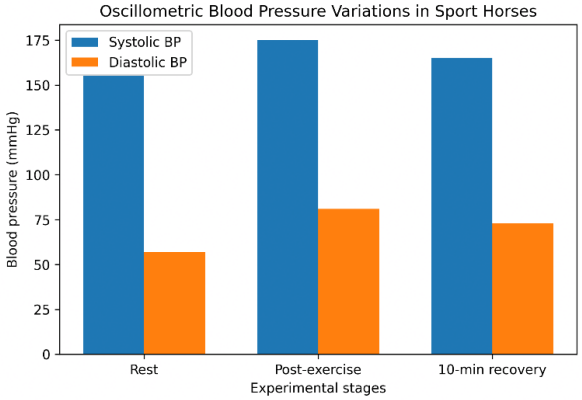

Figure 4. Oscillometric Blood Pressure Variations in Sport Horses During Exercise and Recovery

The obtained systolic blood pressure values showed a progressive increase following exercise, exceeding the physiological interval reported for horses (SBP = 110–160 mmHg). Post-exercise systolic pressure reached 175 mmHg, suggesting transient exercise-induced systolic hypertension, while the persistence of elevated values during recovery indicated incomplete hemodynamic restoration and continued cardiovascular stimulation after training.

Diastolic blood pressure values remained lower than commonly reported reference intervals throughout all investigated stages, with values of 57 mmHg at rest, 81 mmHg post-exercise, and 73 mmHg during recovery. Reduced diastolic

pressure may reflect alterations in peripheral vascular resistance and redistribution of blood flow toward active musculature during physical exertion. In association with increased systolic pressure, these findings resulted in increased pulse pressure amplitude, characteristic of an intense cardiovascular response to exercise.

Overall, the blood pressure profile demonstrated progressive systolic elevation after exercise followed by delayed recovery, suggesting both physiological cardiovascular adaptation mechanisms and delayed vascular and autonomic recovery during the post-training period. Oscillometric blood pressure measurements in horses present considerable variability and should always be interpreted in relation to the clinical status, training level, and physiological condition of the animal. Persistent post-exercise systolic hypertension and delayed normalization may indicate incomplete cardiovascular adaptation to physical exertion [11].

Functional myocardial contractility depends on the energetic availability within cardiomyocytes and on the efficiency of actin–myosin interaction mechanisms, processes essential for myocardial contraction and maintenance of hemodynamic performance. Under physiological conditions, the structural integrity of cardiomyocytes limits the release of cardiac biomarkers into the circulation; therefore, cardiac troponin T is normally present at extremely low or even undetectable serum concentrations in healthy individuals. Increased concentrations are generally associated with myocardial stress, altered membrane permeability, or structural myocardial injury.

The cardiac troponin T values determined before and after exercise are presented in Table 4.

Table 4. Mean values and statistical indices of cardiac Troponin T (pg/nm)

Specification	Mean	Standard Error of the Mean	Standard Deviation	Variance
Before exercise	**2.818**[a]	0.698	1.710	2.923
After exercise	**3.062**[a]	0.739	1.811	3.281

[a-a] $p>0.05$

Before exercise, the mean concentration was 2.818 pg/mL, remaining within the laboratory reference interval. Following the warm-up exercise, the mean value increased to 3.062 pg/mL in the six investigated horses, slightly exceeding the reference threshold. Although no statistically significant differences were identified between pre- and post-exercise values ($p>0.05$), the observed increase may reflect transient myocardial stress associated with physical exertion, increased myocardial metabolic activity, and enhanced cardiomyocyte membrane permeability during exercise.

Statistical evaluation also demonstrated the presence of individual variability, with certain horses showing increased biomarker concentrations both before and after exercise. Similar transient increases in cardiac troponins have been reported in horses following physical activity and are not necessarily associated with severe myocardial injury [5]. Cardiac troponins are considered sensitive biomarkers for detecting subtle cardiomyocyte injury, even in the absence of evident clinical manifestations [12], while high-sensitivity assays have demonstrated that exercise-induced troponin variations may represent an adaptive myocardial response to exertion [13, 14].

Cardiac troponins are also recognized as highly sensitive indicators of myocardial stress and subclinical cardiac injury; however, their interpretation should always be correlated with clinical examination, electrocardiography, echocardiography, and functional cardiovascular assessment [15]. In the present study, the troponin T profile suggests the presence of adaptive myocardial responses to exercise without evidence of major cardiac injury, although periodic cardiovascular monitoring in Sport Horses remains advisable.

Overall, the correlated analysis of electrocardiographic, hemodynamic, and biochemical parameters demonstrated considerable individual variability in cardiovascular adaptation to exercise. Horses presenting rapid heart rate recovery and electrocardiographic indices within physiological limits appeared better adapted to physical exertion, whereas the persistence of tachycardia, increased ventricular systolic index (VSI) values, and elevated systolic blood pressure may indicate increased cardiovascular workload and reduced adaptive capacity. These findings support the necessity of implementing individualized training programs and continuous cardiovascular monitoring protocols based on an integrated

approach including electrocardiography, blood pressure assessment, and cardiac biomarkers.

4. Conclusions

The obtained results highlight the importance of electrocardiography in the functional evaluation of the cardiovascular system in Sport Horses, allowing the early identification of rhythm and conduction disturbances, as well as exercise-associated myocardial alterations. The electrocardiographic changes observed during the investigated stages reflected physiological cardiovascular adaptation to exercise.

Blood pressure analysis revealed post-exercise systolic increases associated with delayed recovery, suggesting increased cardiovascular workload and transient hemodynamic stress. In addition, slight increases in cardiac troponin T concentrations indicated the presence of transient exercise-induced myocardial stress, even in the absence of statistically significant differences.

These findings support the value of periodic cardiovascular monitoring, including electrocardiographic assessment, blood pressure evaluation, and cardiac biomarker analysis, in horses subjected to intensive training. The integration of these investigations with clinical and echocardiographic evaluation may improve the assessment of exercise adaptation and optimize the medical management of performance horses.

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