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Electrocardiographic Parameters in Purebred Kurd Horse

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Abstract: This study was undertaken to determine the normal electrocardiographic parameters of Kurd horse and to compare them with previously published data for other breeds. Electrocardiograms were recorded using Base-Apex lead in 45 purebred Kurd horse aged from 3-28 years old (13 female and 32 male). Heart rate and rhythm, configuration and amplitude of waves and complexes, duration of waves, complexes, intervals and segments and the shape of ST segment were evaluated. The analyses showed that the resting heart rate (mean and standard deviation 32.33±5.54 and range 23-45) of Kurd horse is lower than those of reported from other breeds. Incomplete atrioventricular block was detected in none of the horses. High frequency of wandering pacemaker (28.9%) and sinus arrhythmia (24.4%) and low frequency of sinus block (4.4%) were the other aspect of the heart rhythm in Kurd horse. Significant differences were seen for heart rate, T wave amplitude and duration of PR segment in relation to sex. The results suggest that the electrocardiographic parameters of the Kurd horse are comparable with parameters of elite horses such as Thoroughbred racehorses.

Key words: Electrocardiography, Kurd horse, arrhythmia, amplitude, duration, Iran

INTRODUCTION

Kurd horse breed has been originated from western mountainous areas of Iran. The characteristics of this breed are similar to that of Arab horse. They have strong hooves, wide frontal area, large and beautiful eyes, strong muscular build-up and well shaped neck. They are distributed in western provinces of Iran and have four strains, namely Jaff, Afshari, Sanjabi and Kalhor categorized by their physical appearance, color and their inhabitate. The most important characteristic of this breed is its high endurance competence and ability to live in hard mountainous area and walk in rocky condition.

The Kurdish horse has a known history dating back almost five thousand years ago. Additionally, the vast majority of today's horses possess a great genetics linkage to the Kurdish horse. The breed itself is one of the purest breeds of horse still existing today. It provides owners and riders with a unique combination of strength and endurance alike giving them the opportunity to experience and enjoy a truly magnificent animal, adaptable to a wide range of disciplines and conditions (http://www.kurdishhorse.net/index.htm). Physical performance of sport horses and their ability in tolerating hard physical condition is directly related to the cardiovascular fitness. Several techniques have been developed to assess the health and function of cardiovascular system in sport horses. The electrocardiography is the most accurate method for assessing disturbances of the genesis and spread of the cardiac impulse. A complete cardiovascular examination must include electrocardiography as it offers a very useful means in monitoring and diagnosis of arrhythmias and conduction disturbances. Fregin (1982) studied the electrocardiogram of Thoroughbred and Standardbred horses with standardized body and limb position.

Costa *et al.* (1985) reported the electrocardiographic values in non-trained horses. Ayala *et al.* (1999, 2000) studied the morphology and amplitude values of Spanish-bred horses. Alidadi *et al.* (2002) described the normal electrocardiogrphic parameters of Turkman horse using the standard lead Base-Apex. Others explained some other aspects of horse electrocardiogram (Steel, 1963; Glazier, 1966; Holmes and Alps, 1967; Hamlin *et al.*, 1970a, b; Spark 1970; Holmes and Rezakhani, 1975; Muylle and Oyaert, 1977). Little information is available

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regarding various characteristics of Kurd horse including their cardiovascular parameters. The present study was undertaken to determine the normal electrocardiographic parameters of Kurd horse and to compare them with previously published data for other breeds.

MATERIALS AND METHODS

The study was carried out on 45 clinically healthy registered Kurd horses, 13 nonpregnant females and 32 males ranging in age from 3-28 years old. The horses underwent a thorough clinical examination and only those showing no abnormalities were included in the study. All recording were taken without sedation and physical restraint while horses were standing in their stall. ECG recordings were obtained using base-apex lead. For each recording the negative electrode of lead I was attached to the skin of the left jugular furrow in the lower third of the neck and the positive electrode of lead I was attached to the skin of the thorax behind the left elbow over the area of apex beat using alligator clamps (Robertson, 1990). The forelimbs were kept parallel to each other and perpendicular to the long axis of the animal's body (Fregin, 1982; Costa *et al*., 1985). The ECGs were recorded using a portable single-channeled electrocardiography unit (Nihon Kodhen) over approximately 3 min at a paper speed of 25 mm sec^{-1} and a voltage calibration of 5 mm equal to 1 mV. After attaching the electrodes and before any recording, the horses were allowed some time (about 5 min) to adapt so that the electrocardiograms were taken from relaxed animals. Electrocardiograms were analyzed for heart rate and rhythm, configuration, amplitude and duration of P wave, QRS complex and T wave, duration of PR and QT intervals and ST segment and deviation of ST segments from baseline according to the method described by others (Fregin, 1982; Holmes and Alps, 1967).

The P wave was categorized to bifid, single peaked and biphasic. In an attempt to get best results according to Fregin (1982) the P waves were divided to two components P_1 and P_2. T wave also categorized in four groups consisting of positive, negative or diphasic +/- or -/+. Statistical analysis was performed using SPSS 16 for windows (SPSS Inc, Chicago, Il, USA). Before statistical analysis, data were confirmed to be normally distributed using the Kolmogorov-Smirnov test. Descriptive statistics including mean, standard deviation and range for the electrocardiographic parameters were calculated. Influence of sex on ECG parameters was compared using Student's t test. Results are expressed as means±standard deviation. The level of significance was defined as $p<0.05$.

RESULTS AND DISCUSSION

The evaluation of cardiac rhythm revealed that in all 45 horses the rhythm was under control of sinoatrial node though, the rhythm was not regular in 20 (44.4%) horses. Five horses (11.1%) showed sinus arrhythmia and in six horses (13.3%) sinus arrhythmia was accompanied with wandering pacemaker. In seven horses (15.6%) wandering pacemaker was observed without sinus arrhythmia. Therefore, on the whole sinus arrhythmia and wandering pacemaker were detected in 11 (24.4%) and 13 horses (28.9%), respectively. Sinoatrial block was observed in two horses (4.4%). Twenty-five horses (55.6%) had regular sinus rhythm. The mean (±SD) and range for heart rate were 32.3 (±5.6) and 22-45 beat min^{-1}, respectively. In the females heart rate (36.5±5.6) was significantly higher than those of male horses (30.7±4.8). The statistics for electrocardiographic parameters are shown in Table 1-4. In 43 of 45 horses (95.6%) the configuration of P wave was bifid and in two horses (4.4%) it was biphasic (+/-) (Table 1). No significant differences were observed in P wave parameters between genders.

Three different configuration of the ventricular depolarization complexes were detected on the ECG traces. The rS was the most frequently recorded configuration (80.0%) followed by QRS (11.1%) and QS (8.9%) morphology. Q-wave was detected only in five horses (%11.1) however, in 41of horses (91.1%) R and S waves (as rS and QRS configuration) were present

Table 1: Amplitude (mV) of electrocardiographic parameters in 45 Kurd horses on base-apex lead

			Range		
Parameters	Number	Relative frequency (%)	Min.	Max.	Mean±SD
Bifid (P_1)	43	95.6	0.03	0.80	0.21±0.14
P wave (P_2)	43	86.7	0.25	0.90	0.42±0.12
Biphasic (-, component)	2	4.4	-0.20	-0.05	-0.12±0.11
P wave (+, component)	2	4.4	0.40	0.50	0.45±0.07
Q wave	5	11.1	0.05	0.15	0.08±0.04
R wave	41	91.1	0.05	1.50	0.50±0.35
S wave	41	91.1	1.50	4.00	2.85±0.47
QS complex	4	8.9	2.90	4.00	3.25±0.51
Monophasic T wave (+)	1	2.2	0.60	0.60	0.60±0.00
Monophasic T wave (-)	1	2.2	-1.30	-1.30	1.30±0.00
Negative component of T (-/+)	43	95.6	-0.10	-1.80	0.78±0.45
Positive component of T (-/+)	43	95.6	0.05	0.90	0.39±0.21

Table 2: Duration (sec) of electrocardiographic parameters in 45 Kurd horses on base-apex lead

Parameters	Range	Mean±SD
P wave duration	0.08-0.16	0.13±0.02
QRS complex duration	0.10-0.16	0.13±0.02
T wave duration	0.12-0.20	0.16±0.02
PR interval	0.20-0.38	0.29±0.04
QT interval	0.44-0.64	0.51±0.04
PR segment	0.08-0.28	0.16±0.04
ST segment	0.16-0.32	0.22±0.03

Table 3: Comparison of heart rate (beat min^{-1}) and amplitude (mV) of electrocardiographic parameters in male and female Kurd horses

Parameters	Gender	Number	Mean±SD
Heart rate	Male	32	30.65±4.82*
	Female	13	36.46±5.55
P_1 component of bifid P wave	Male	30	0.20±0.14
	Female	13	0.21±0.15
P_2 component of bifid P wave	Male	30	0.43±0.13
	Female	13	0.40±0.10
R wave	Male	30	0.55±0.35
	Female	11	0.38±0.31
S wave	Male	32	2.89±0.46
	Female	12	2.76±0.53
Negative component of T wave (-/+)	Male	32	0.88±0.42*
	Female	11	0.48±0.42
Positive component of T wave (-/+)	Male	32	0.34±0.18*
	Female	11	0.52±0.24

*Significant difference between gender at $p<0.05$

Table 4: Comparison of duration (sec) of electrocardiographic parameters in male and female Kurd horses

Parameters	Gender	Mean±SD
P Wave	Male	0.13±0.021
	Female	0.13±0.019
QRS complex	Male	0.13±0.018
	Female	0.13±0.017
T wave	Male	0.17±0.024*
	Female	0.15±0.014
PR interval	Male	0.28±0.038
	Female	0.30±0.044
QT interval	Male	0.52±0.040*
	Female	0.48±0.038
PR segment	Male	0.15±0.039*
	Female	0.18±0.028
ST segment	Male	0.22±0.032
	Female	0.22±0.032

*Significant difference between gender at $p<0.05$

(Table 1). There was no significant difference between sexes in ventricular depolarization complexes parameters (Table 3 and 4). Assessment of ECG traces revealed two configurations for the T wave. The biphasic -/+ configuration was the most frequently observed morphology which was detected in 43 of horses (95.6%). In two horses (4.4%) monophasic T wave including one positive and one negative T was detected (Table 1). The amplitude of negative and positive components of biphasic T wave in males and females, respectively was significantly higher than those of other sex (Table 3). In addition, the T wave duration in males was longer than those in females ($p<0.05$) (Table 4).

The PR and QT interval duration range was from 0.2-0.38 and 0.44-0.64 sec, respectively (Table 2). The male horses had a significantly longer mean duration of QT interval than did the female horses. The range of PR and ST segment duration was 0.08-0.28 and 0.16-0.32 sec, respectively (Table 2). Gender was not significantly associated with the duration ST segment however, the male horses had significantly longer mean duration of PR segment than did the female horses (Table 4). In 34 (76%) of the horses the shape of ST segments was descending. In 9 (20%) horses it was straight and in 2 (4%) horses it was ascending. In descending form the range of differences between the highest point at the end of S-wave and the lowest point at the beginning of T wave was -0.1 to 0.4 mV. In the ascending form the differences between two points were 0.1 and 0.15 mV. Resting heart rate has been considered as a measure of an animal physically fitness and a strong indicator of cardiovascular system health. Reported values of heart rate ranged from 26-46 with a mean of 36.1 beat min^{-1} for Thoroughbred horses (Fregin, 1982) from 26-50 with mean of 34.8 beat min^{-1} for Standardbred horses (Fregin, 1982), from 32.89-35.83 with a mean of 34.2 beat min^{-1} for Sella Italiana breed (Piccione *et al*., 2003) from 20-49 with a mean of 34.2 beat min^{-1} for Turkman horses (Alidadi *et al*., 2002). In the study reported here, the range of heart rate was 23-45 beat min^{-1} and the mean value was 32.3 which is the lowest reported value for horse so far. Such a lower resting hear rate reflect the health of circulatory system and could be considered as an indicator of basic fitness level in Kurd horses. Horses with larger hearts have slower heart rate which reflects larger stroke volume (Stewart and Steel, 1970). The competences of Kurd horses in tolerating very high intensity exercises and endurance rides might be related to their unique cardiovascular system characteristics, including the heart rate.

Clinically insignificant cardiac arrhythmias (benign or physiologic arrhythmias) were observed on the traces of 44.4% of Kurd horses. In normal horses at rest, the presence of benign arrhythmias including sinus arrhythmia, wandering pacemaker and sinoatrial block are most often associated with increase in vagal tone rather than primary cardiac disease. However, second degree atrioventricular block which has been considered as the most common vagally mediated conduction disturbances in equine population particularly in fit horses, (Radostits *et al*., 2007) was not observed in Kurd horses. In accordance with the present study, Fregin (1982) also did not detect any case of second degree atrioventricular block in Standardbred horse. P wave in horse is a variable wave and has several configurations. Its amplitude and shape depends on the position of the electrodes on the

body surface (Glazier, 1966) and the vagal tone (Fregin, 1982). In the Kurd horses, the P wave was predominantly bifid (95.6%) which agree with studies in other breeds (Hamlin *et al*., 1970b; Fregin, 1982; Costa *et al*., 1985; Ayala *et al*., 1999). First component of P wave (P1) is quite labile and is completely influenced with autonomic nervous system tone whereas change in autonomic tone has little effect on second component of P wave (P2) (Fregin, 1982). P1 is the result of right atrial activation whereas P2 arises from activation of the interatrial septum and associated structures (presumably Bachmann's bundle), activation of the left atrium is electrocardiographically silent (Hamlin *et al*., 1970a). In 43 (95.6%) horses P wave was bifid and in 2 (4.4%) horses was biphasic (-/+). In Spanish-bred horse Biphid pattern (69.32%), positive single (26.24%) picked and biphasic P wave (-/+) (4.42%) were seen (Ayala *et al*., 2000). In Turkman 85.20% of the P wave were bifid (Alidadi *et al*., 2002) and in Mangalarga Marchador breed 68.3, 25 and 6.7% were the percentage of bifid, positive single picked and biphasic P wave respectively. Amplitude of P1 wave in Kurd horses was 0.8-0.03 mV with mean value of 0.21±0.14 mV and about P2 it was 0.25-0.9 mV with mean value of 0.42±0.12. In biphasic form range of P1 amplitude was -0.05 to -0.20 mV with mean value of -0.12±0.11 mV and in P2 that was 0.4-0.5 mV and 0.45±0.07 mV, respectively. P wave amplitude range in Turkman horses was -0.175-0.385 with mean value of 0.205±0.008 (Alidadi *et al*., 2002) and mean value in Mangalarga Marchador breed was 0.307±0.009. The mean duration of P wave was 0.13±0.02 sec with the range of 0.08-0.16 sec.

The P wave duration in Turkman range from 0.06-0.17 with mean value of 0.128 (Alidadi *et al*., 2002) and in Mangalarga Marchador breed mean value was 0.121±0.004. P wave duration and amplitude are useful electrocardiographic parameters in prediction of heart function. Exercise may increase the amplitude of the P wave in contrast increased vagal tone that may occur during slowing of the heart rate may decrease the amplitude of P wave (Glazier, 1966). The amplitude of P wave in Kurd horses was more than other breeds which may be attributed to lesser vagal tone in Kurd horses compared to other breeds (Glazier, 1966).

The reason and importance of larger amplitude of P wave in Kurd horses is not clear. There is a positive correlation between P wave amplitude and heart rate (Tilley, 1992; Hanton and Rabemampianina, 2006). However, as the heart rate in Kurd horses was lesser than other breeds, the larger amplitude of P wave cannot be attributed to heart rate in the current study. In humans, increased P wave amplitude and notching are occasionally noted with athletic heart syndrome (Huston *et al*., 1985; George *et al*., 1991). PR interval has no significant change in different breed. In Kurd horses PR interval was 0.2-0.38 sec. In Thoroughbred and Standardbred it was 0.24-0.56 and 0.22-0.49 sec, respectively (Fregin, 1982). Andabout Turkman it recorded 0.21-0.44 sec (Alidadi *et al*., 2002). The configuration of ventricular depolarization (QRS complex) in the body surface electrocardiogram is predominantly defined by the pattern of local depolarization in the apical third of the interventricular septum (Muylle and Oyaert, 1977). In the base-apex lead, the ventricular depolarization is usually recorded as a small positive deflection followed by a large negative deflection (rS). In the present study, the configuration of ventricular depolarization was mainly rS (80%) which agrees with the described patterns for other breeds of horse (Alidadi *et al*., 2002; Ayala *et al*., 2000; Fregin, 1982). The range of Q-wave amplitude was -0.05-0.15 mV and with mean value of 0.08±0.04 mV. About R-wave the maximum amplitude was 1.5 mV and minimum amplitude was 0.05 mV and mean value of 0.51±0.35 mV was seen. In all horses S-wave was present. The maximum and minimum amplitude of QS was 4 and 2.9 mV, respectively with mean value of 3.3±0.51 mV.

QRS complex characteristics are important for the prediction of other heart factor namely heart score. QRS duration is a useful parameter to estimating of horse's performance. There is a correlation between the QRS duration and QT interval, QT interval is a direct measure of the duration of ventricular electrical systole (Stewart and Steel, 1970). Duration of ventricular electrical systole reflects ventricular mass and size of the heart affects the duration of the QT interval (Glazier, 1966; Stewart and Steel, 1970). Range of QRS duration in Kurd horses was 0.1-0.16 sec with mean value of 0.13±0.02 sec. There was no significant differences between sexes in QRS complex parameters. The duration of QT interval in human athletes is increased in response to endurance exercise and the degree of prolongation is dependent to the level of training (Zehender *et al*., 1990). It has also been reported that canine endurance athletes have an increased R wave amplitude, QRS duration and QT interval compared with untrained dogs (Constable *et al*., 1994). Trained horse athletes have larger QT interval because of their larger heart mass (Costa *et al*., 1985).

The duration of QRS complex in Kurd horses was longer than that reported for several breeds including Turkman (Alidadi *et al*., 2002) Mangalarga Merchador and comparable to that of Thoroughbred and Standardbred horses (Fregin, 1982). In addition, the QT interval in Kurd horses was nearly as same as the Thoroughbred and longer than those of other breeds (Alidadi *et al*., 2002; Fregin, 1982). These findings would suggest that the heart size and score in Kurd horses is comparable to Thoroughbred and may be better than other breeds. There

is an inverse correlation between the QT interval and the heart rate (Steel, 1963; Detweiler and Patterson, 1972). The male horses had significantly a longer QT interval than female horses which could be due to higher heart rate in the females and better heart score in males. The T wave is the most variable wave in electrocardiogram and is effected by multiple factors including autonomic nervous system (Fregin, 1982), temperature, age, electrolyte changes, myocardial injury (Spark, 1970) and the rate oxygenation of myocardium by coronary circulation (Spark, 1970; Holmes and Rezakhani, 1975).

Several configurations of the T wave have been reported from horse. It can be either uniphasic or biphasic and either positive or negative (Fregin, 1982). In 95.6% of Kurd horses the most frequently observed configuration of T wave was biphasic negative/positive in which the amplitude of negative phase was notably larger than the positive phase The range of negative component was -0.1-1.8 mV with mean value of -0.78±0.45 mV and it was 0.05-0.9 mV with mean value of 0.39±0.21 mV in positive component. Kurd horses P wave amplitude is approximately accordance with other breeds but the negative component in Turkman was larger than other breed (Alidadi *et al*., 2002; Ayala *et al*., 2000; Fregin, 1982). During exercise the T wave become positive and after exercise and in recovery period it returns to pre-exercise shape (Spark, 1970; Holmes and Rezakhani, 1975).

The quicker the recovery rate, the quicker the T wave inversion time. It is suggested that in horses with properly oxygenated myocardium, the T wave is mainly negative or is the same in polarity to the QRS complex (Spark, 1970). Therefore, the larger negative phase of T wave in Kurd horses may be considered as an indication of a good oxygenation of heart in Kurd horses. In addition, the amplitude of negative phase of T wave was significantly higher in males than in females and positive part was significantly higher in females than in males. The reason for this difference is not clear however, better oxygenation of myocardium in males than in females in response to higher levels of athletic training could be among the probable possibilities. It is important to mention that in the region of the study, the male horses undergo more intense training and racing programs and therefore reach to a higher fitness level of performance than females.

CONCLUSION

Results of the present study suggest that the electrocardiographic parameters of the Kurd horses are comparable with parameters of elite horses such as Thoroughbred racehorses. The potential of the Kurd horses in performing a diverse athletic programs and strenuous exercise, particularly in endurance competitions is of particular interest and suggestive of high level of cardiovascular capabilities in this breed. A thorough study of cardiovascular system with sophisticated techniques to evaluate indices of cardiovascular function, together with other measurements of exercise capacity analysis are necessary to characterize the athletic performance in Kurd horses.

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