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Six-limb-lead electrocardiogram in common dog breeds: reference values

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Abstract

The objective of this study was to establish the standard electrocardiographic (ECG) values for six dog breeds and to evaluate the influence of gender and age on various ECG parameters. Labrador Retrievers (22), Pomeranians (11), mongrels (13), German Shepherds (10), Golden Retrievers (13) and Gaddi dogs (9) were included in the study. Dogs were positioned in right lateral recumbency without the use of any chemical restraint and six-lead ECGs were recorded, comprising three bipolar standard limb leads (I, II and III) and three augmented unipolar limb leads (aVR, aVL and aVF). Parameters like amplitude, duration of P-wave, QRS complex, PR interval, QT interval, mean electrical axis and heart rate were measured for each recording. Amplitude and durations of ECG waves across all six leads were not statistically affected by gender or age. P(mV) was significantly greater in Pomeranians as compared to mongrels whereas, Gaddi breed showed significantly greater Q(mV) as compared to Golden Retrievers.

Key words: Augmented baseline data, unipolar lead, ECG, Gaddi dog

Electrocardiography (ECG) is a valuable tool for assessing parameters such as heart rate (HR), cardiac rhythm, conduction integrity and the theoretical axis of the heart (De Caterina *et al*. 2012). Traditionally, ECGs of healthy dogs have been analysed using standard bipolar limb lead I, which provides information in only one direction. However, clinical situations involve three-dimensional aspects that are more complex. Therefore, multiple electro cardiographic leads are necessary to capture the variations in heart distribution within the thorax (Hsieh and Hsu, 2012).

Studies have shown significant breed differences in ECG parameters among healthy dogs, which could be attributed to variations in shape of thoracic cavities or genetic differences (Avizeh *et al*. 2010). This study aimed to establish a comprehensive set of ECG reference values and assess the influence of breed, sex, and age on the electrocardiogram of six breeds of dogs. It is widely employed in diagnosing various cardiac conditions in humans and animals, including cattle and small ruminants (Pavan *et al*. 2015) and horses (Scheffer *et al*. 1995) as well as in assessing non-cardiac illnesses. In dogs, cardiac arrhythmias and intra-cardiac conduction disturbances are common issues that can be effectively analysed using ECG (Gugjoo *et al*. 2014).

However, there is a lack of comparative studies examining variations in ECG parameters among different dog breeds. Therefore, this study aims to assess the variation in ECG parameters among different breeds of dogs, namely Labradors, Pomeranians, Mongrels, German Shepherds, Golden Retrievers and Gaddi. Additionally, there is a lack of data regarding the basic cardiac parameters of these dogs in specific geo-climatic regions. It is anticipated that the data generated from this study will be valuable for future assessments in this field.

Materials and Methods

The study involved 78 clinically healthy dogs of either gender from locations in and around Palampur, H.P., India. The dogs were categorized into six different breeds: Labradors (n=22), Pomeranians (n=11), mongrels (n=13), German Shepherds (n=10), Golden Retrievers (n=13) and Gaddis (n=9). Age-based classification was carried out into three subgroups: (i) <2 years, (ii) 2–6 years and (iii) >6

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years.

A 3-channel RMS Vesta 301i ECG machine was used to capture the electrographic recordings, with calibration and gain set to 10 mm=1 mV and paper speeds of 50 and 25 mm/s. On thermosensitive ECG paper, recordings were made from all of the standard bipolar limb leads (Lead-I, II and III) as well as the unipolar augmented limb leads (Lead - aVR, aVL and aVF). The small square on the horizontal axis indicates 0.02 seconds. Wave amplitude or voltage is shown on the vertical axis, where 0.1 mV is represented by a 1 mm height. All of the dogs were kept in right lateral recumbency and manually restrained without the use of anaesthesia at the time the recording was made.

Measurement of Heart rate, complexes, intervals, and mean electrical axis (MEA)

Waves of ECG recorded by Lead II are considered to be the typical waves as the depolarization vector is directed toward the electrode of Lead II (Becker *et al*. 2006). Amplitudes of P, Q, R, S and T-waves were measured together with PR interval, QRS interval and QT interval. HR was calculated by successive R-R interval.

The procedures outlined by Edwards (2000) were followed to calculate the mean electrical axis-

1) Mean Electrical Axis was identified by locating the isoelectric lead on the ECG.
2) The six-axis reference chart revealed a lead that was perpendicular to the isoelectric lead.
3) The MEA value is determined by the electrocardiogram's positive or negative perpendicular lead deflection.

Statistical analysis

Using computer software Instat from Graphpad software, the collected data was statistically analysed. The mean values of different parameters between control and diseased group, pre and post treatment were compared at 5% and 1% level of significance using "t" test and "ANOVA".

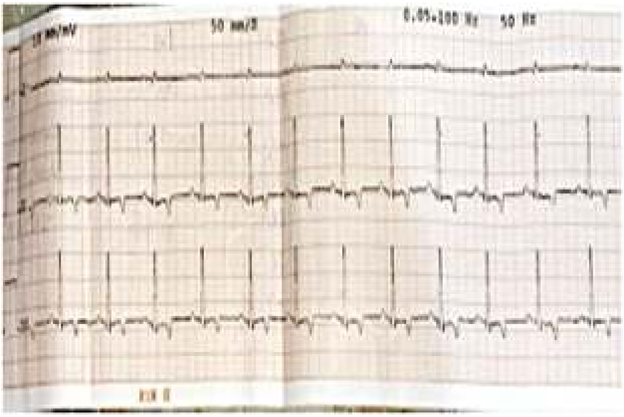
Results and Discussion

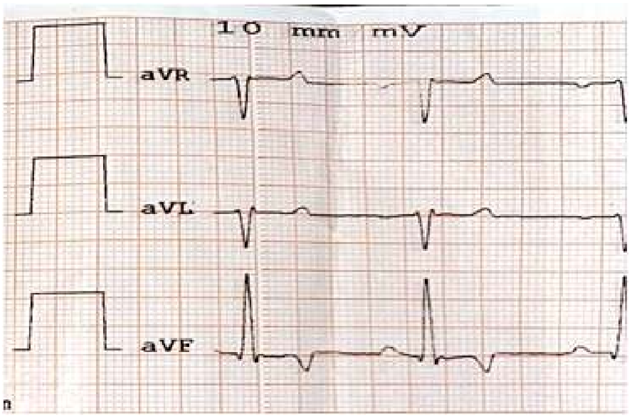
Mean ± SEM of different ECG parameters (Lead II) in different breeds of dogs has been presented in Table1. The ECG parameter reference values for the various dog breeds in this investigation were found to be consistent with previous reports in the German Shepherd (Rezakhani *et al*. 1990), Labrador (Gugjoo *et al*. 2014), and Beagle (Detweiler *et al*. 1997). Fig. 1-6 represents the normal electrocardiograph of healthy dogs in different breeds.

There were no significant variations in HR among different breeds. Though HR was found to be highest in Pomeranians (134 ±15.49 bpm) followed by German Shepherd (125.3±11.25 bpm), Gaddi (123.33±6.67 bpm), Golden Retriever (116.67 ± 6.67 bpm), Labrador (111.67± 9.46) and Mongrel (108.75 ± 5.26 bpm).Heart rate in the current investigation was found to be comparable to the reference values given by Becker (2006).

P-amplitude was maximum in Pomeranians (0.18 ± 0.03 mV) followed by Gaddi (0.16 ± 0.03 mV), Labradors (0.16 ± 0.02 mV), Golden retriever (0.15 ± 0.04 mV), German Shepherd (0.13 ± 0.03mV) and mongrels (0.10 ± 0.02 mV). Pomeranians showed statistically ($p<0.05$) greater P(mV) as compared to mongrels, but within normal range. The P-wave amplitude travels from the Sinoatrial node to the Atrioventricular node and represents the degree of atrial depolarization. Pomeranian breeds showed a higher HR (134 ± 15.49 bpm) than the other five breeds studied, which could account for the breeds' higher P-wave amplitude. According to Avizeh *et al*. (2010) and Ferasin *et al*. (2012), stress displayed during ECG recording may account for variation in P-wave amplitude. Additionally, Mukherjee *et al*. (2020) noted that stress and heart rate may be related to variations in P wave amplitude. In all six limb leads, the gender influence on the P wave was found to be non-significant. These findings were consistent with the results of several earlier studies (Hanton and Rabemampianina 2006 and Changkija 2007).

Q-amplitude was maximum in Gaddi dogs (0.25±0.03 mV) followed by Pomeranians (0.21±0.02 mV), mongrels (0.18±0.03 mV), Labradors (0.18±0.02 mV), German Shepherds (0.17±0.03 mV) and Golden Retrievers (0.15±0.03mV). Gaddi breed showed statistically ($p<0.05$) greater Q(mV) in comparison to Golden retrievers but within normal range. Rest all ECG parameters varied non-significantly within normal ranges among different breed under study (Table 1). Q-wave of QRS complex produced due to ventricular depolarization and the electrical transmission through interventricular septum after P-

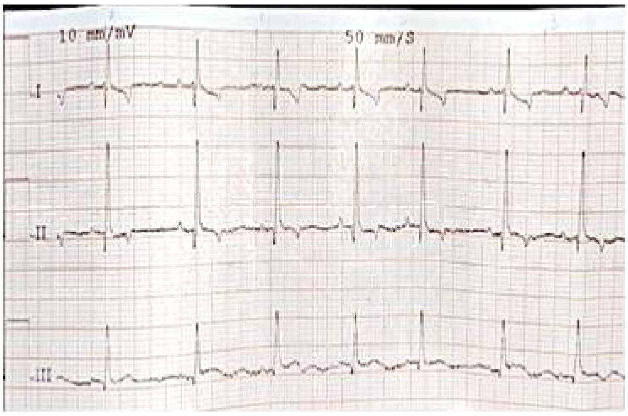


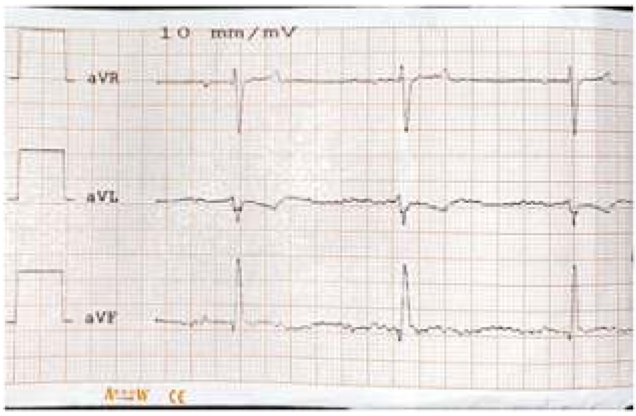


(a) Standard bipolar limb lead I, II and III

(b) Augmented unipolar lead avR, avL and aVF

Fig 1 Electrocardiograph in healthy Labrador dog (Speed: 50mm/sec)

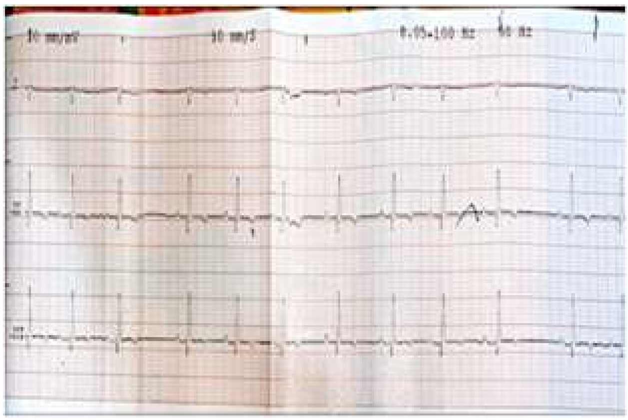
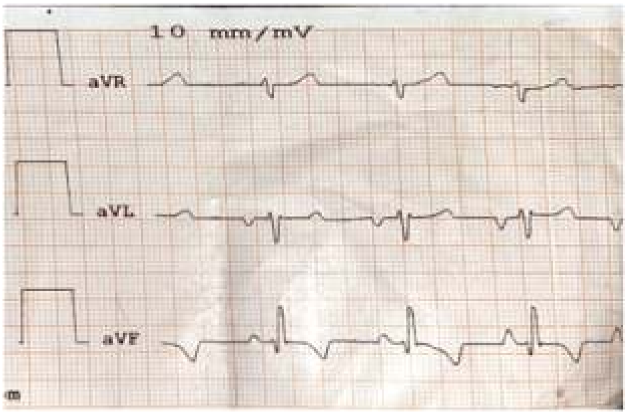




(a) Standard bipolar limb lead I, II and III

(b) Augmented unipolar lead avR, avL and aVF

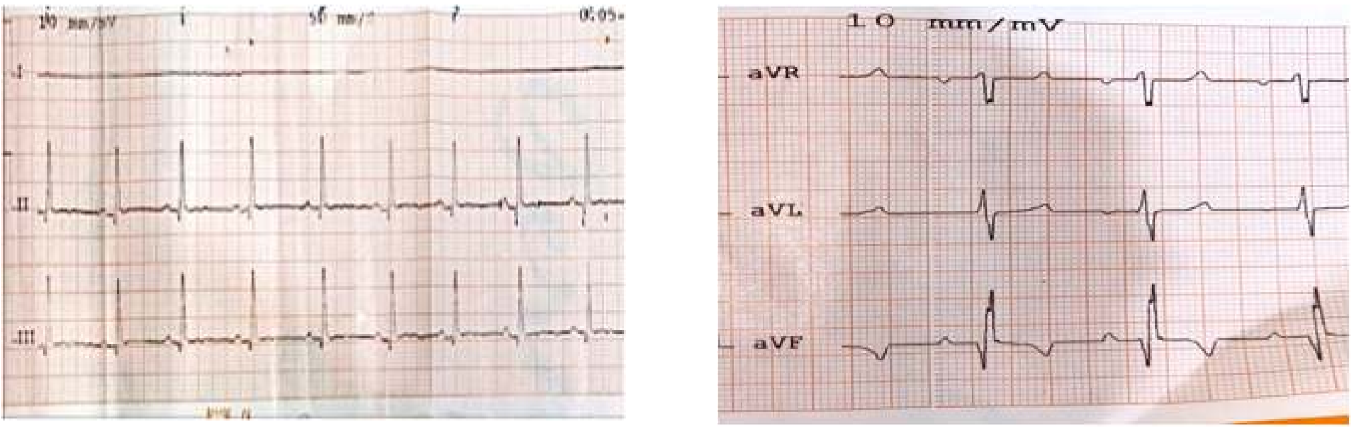
Fig 2 Electrocardiograph in healthy Pomeranian dog (Speed: 50mm/sec)

(a) Standard bipolar limb lead I, II and III

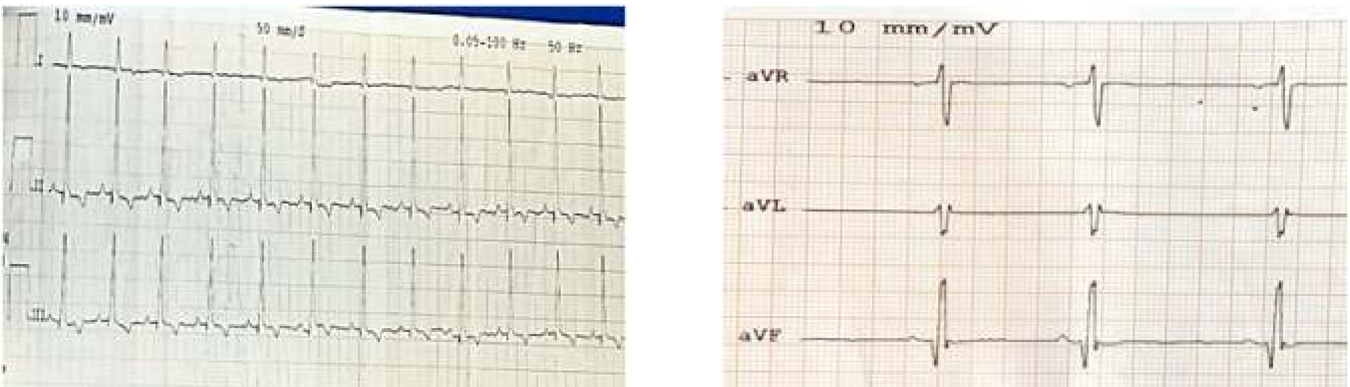
(b) Augmented unipolar lead avR, avL and aVF

Fig 3 Electrocardiograph in healthy mongrel dog (Speed: 50mm/sec)



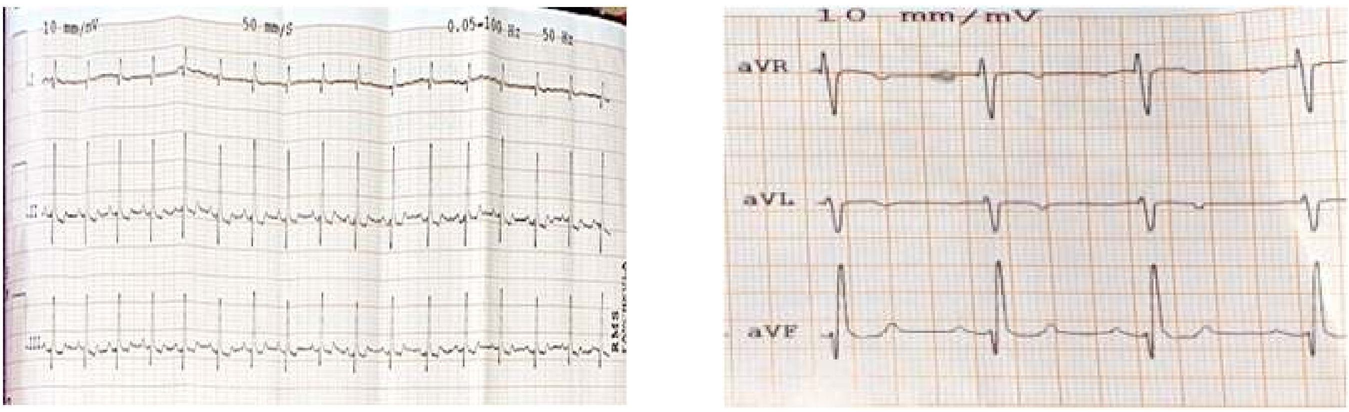
(a) Standard bipolar limb lead I, II and III (b) Augmented unipolar lead avR, avL and aVF

Fig 4 Electrocardiograph in healthy German Shepherd dog (Speed: 50mm/sec)



(a) Standard bipolar limb lead I, II and III (b) Augmented unipolar lead avR, avL and aVF

Fig 5 Electrocardiograph in healthy Golden Retriever dog (Speed: 50mm/sec)



(a) Standard bipolar limb lead I, II and III (b) Augmented unipolar lead avR, avL and aVF

Fig 6 Electrocardiograph in healthy Gaddi dog (Speed: 50mm/sec)

Table 1. Reference ECG parameters categorised breed, age, and gender wise

	Heart Rate (bpm)	P-wave amplitude (mV)	P-wave duration (sec)	Q-wave amplitude (mV)	PR-interval (sec)	R-wave amplitude (mV)	QRS duration (sec)	T-wave amplitude (mV)	T-wave duration (sec)	QT segment (sec)	RR-interval (sec)	MEA
Selected Breed												
Labrador (n=22)	111.67 ± 9.46[a]	0.16 ± 0.02[ab]	0.04 ± 0.001[a]	0.18 ± 0.02[ab]	0.10 ± 0.001[a]	1.20 ± 0.16[a]	0.05 ± 0.002[a]	0.17 ± 0.02[a]	0.04 ± 0.00[a]	0.19 ± 0.01[a]	0.55 ± 0.07[a]	67.5 ± 4.09[a]
Pomeranian (n=11)	134 ± 15.49[a]	0.18 ± 0.03[a]	0.03 ± 0.001[a]	0.21 ± 0.02[ab]	0.08 ± 0.01[a]	1.10 ± 0.21[a]	0.04 ± 0.01[a]	0.20 ± 0.03[a]	0.05 ± 0.01[a]	0.17 ± 0.02[a]	0.52 ± 0.09[a]	56.36 ± 6.42[a]
Mongrel (n=13)	108.75 ± 5.26[a]	0.10 ± 0.02[b]	0.03 ± 0.001[a]	0.18 ± 0.03[ab]	0.10 ± 0.01[a]	0.89 ± 0.18[a]	0.04 ± 0.002[a]	0.18 ± 0.05[a]	0.06 ± 0.01[a]	0.18 ± 0.01[a]	0.47 ± 0.09[a]	56.92 ± 5.83[a]
German Shepherd (n=10)	125.3 ± 11.25[a]	0.13 ± 0.03[ab]	0.03 ± 0.01[a]	0.17 ± 0.03[ab]	0.10 ± 0.01[a]	1.18 ± 0.11[a]	0.05 ± 0.01[a]	0.22 ± 0.05[a]	0.06 ± 0.01[a]	0.19 ± 0.01[a]	0.51 ± 0.11[a]	71 ± 6.74[a]
Golden Retriever (n=13)	116.67 ± 6.67[a]	0.15 ± 0.04[ab]	0.04 ± 0.002[a]	0.15 ± 0.03[a]	0.09 ± 0.01[a]	1.18 ± 0.64[a]	0.04 ± 0.002[a]	0.20 ± 0.04[a]	0.05 ± 0.00[a]	0.17 ± 0.03[a]	0.48 ± 0.12[a]	75.38 ± 5.62[a]
Gaddi (n=9)	123.33 ± 6.67[a]	0.16 ± 0.03[ab]	0.04 ± 0.01[a]	0.25 ± 0.03[b]	0.09 ± 0.01[a]	0.95 ± 0.30[a]	0.05 ± 0.001[a]	0.20 ± 0.02[a]	0.06 ± 0.01[a]	0.18 ± 0.01[a]	0.39 ± 0.11[a]	76.67 ± 5.27[a]
Age												
<2 years (n=17)	158.26 ± 5.32[a]	0.13 ± 0.01[a]	0.0315 ± 0.0016[a]	0.22 ± 0.01[a]	0.08 ± 0.005[a]	1.04 ± 0.08[a]	0.04 ± 0.001[a]	0.16 ± 0.03[a]	0.04 ± 0.005[a]	0.17 ± 0.01[a]	0.45 ± 0.04[a]	55.6 ± 5.56[a]
2-6 years (n=31)	111.41 ± 4.07[b]	0.16 ± 0.02[a]	0.0374 ± 0.0024[ab]	0.27 ± 0.02[a]	0.09 ± 0.002[ab]	0.98 ± 0.11[a]	0.04 ± 0.004[a]	0.20 ± 0.01[a]	0.05 ± 0.005[a]	0.19 ± 0.00[a]	0.51 ± 0.05[a]	69.75 ± 5.11[a]
>6 years (n=30)	105.58 ± 4.98[b]	0.17 ± 0.02[a]	0.041 ± 0.0023[b]	0.19 ± 0.07[a]	0.11 ± 0.003[b]	1.12 ± 0.12[a]	0.05 ± 0.003[a]	0.20 ± 0.02[a]	0.05 ± 0.01[a]	0.19 ± 0.01[a]	0.51 ± 0.05[a]	74.65 ± 8.75[a]
Gender												
Male (n=56)	121.11 ± 4.03[a]	0.15 ± 0.07[a]	0.04 ± 0.01[a]	0.24 ± 0.02[a]	0.09 ± 0.02[a]	1.04 ± 0.58[a]	0.04 ± 0.01[a]	0.18 ± 0.17[a]	0.05 ± 0.02[a]	0.19 ± 0.04[a]	0.49 ± 0.26[a]	67.67 ± 4.83[a]
Female (n=22)	126.67 ± 9.40[a]	0.18 ± 0.11[a]	0.03 ± 0.01[a]	0.29 ± 0.04[a]	0.09 ± 0.02[a]	1.20 ± 0.72[a]	0.04 ± 0.02[a]	0.20 ± 0.19[a]	0.04 ± 0.02[a]	0.17 ± 0.02[a]	0.48 ± 0.25[a]	56.29 ± 5.88[a]

Mean ± SE values with different superscript in same column are considered significant ($p<0.05$)

wave. Q (amplitude) was significantly greater in Gaddi dogs when compared to Golden Retrievers. According to Sato *et al*. (2000), variations in Q wave amplitude among breeds may be linked to thoracic characteristics in individual dogs. This observation may be explained by the thoracic idiosyncrasies of various dog breeds as well as the relationship between the depth of the Q wave and the activation processes of the cardiac ventricles, or by variations in the distribution of purkinje fibres within the ventricular walls. According to Bernal *et al*. (1995), statistical study based on age and sex revealed non-significant differences in the Q wave amplitude which was consistent with our results.

The primary ventricular muscles' depolarization is represented by the R wave, which is used to assess left ventricular function. In the current study, we found that while R wave did not differ significantly amongst breeds. Labrador, GSD and Golden Retrievers had non-significantly higher values. Previous studies by Mukherjee *et al*. (2020) also reported that larger dog breeds have higher R wave amplitudes than smaller breeds because of larger ventricular surfaces and thicker walls.

The QT interval is a dynamic physiological characteristic that can be changed by the velocities of both ventricular conduction and repolarization. The QT interval in this investigation was consistent with previous publications (Gugjoo *et al*. 2014 and Mattera *et al*. 2012).

According to previous observations (Gugjoo *et al*. 2014 and Kumar *et al*. 2011), T-wave amplitude and duration, which are directly related to the repolarization of the ventricular myocardial cells, were determined to be within normal range in the current investigation. In our investigation, inverted T-waves were frequently observed. While the altered polarity of the T-wave in Lead II may be induced by elevation of the diaphragm during breathing, the genesis of the T-wave is highly complex (Tilley 1992; Kumar *et al*. 2014), and the factors determining T-wave polarity are still not well known (Potse *et al*. 2007).

As previously reported by Gugjoo *et al*. (2014), MEA values of the heart in several breeds of dogs under investigation were determined to be within the normal range.

Under age wise categorization, dogs below 2 years of age showed highest heart rate with mean ± SEM of 158.26±5.32 bpm which was significantly greater than other age groups probably due to higher metabolic rate in growing pups. Also, the geriatric age group (>6 years) showed longer P(duration) - 0.041 ± 0.0023 sec when compared to other age groups and showed significant variation ($p<0.05$) with younger age group (<2 years). Similarly, PR(sec) in geriatric group (>6 years) was more - 0.11 ± 0.003sec in comparison to other groups and showed statistical variation ($p<0.05$) with the younger age group (<2 years). The rest of the ECG parameters varied non-significantly among different age groups. Gender wise classification revealed no statistical variations among ECG parameters as shown in Table 1.

Conclusion

The present study provides the reference values for different ECG parameters in Labrador, Pomeranian, mongrel, German Shepherd, Golden Retriever and Gaddi dog breeds acclimatized to Indian climate with cardiovascular adjustments. This study found significant differences with respect to the Q (amplitude) between the Gaddi and Golden Retrievers and P (amplitude) among Pomeranians and Mongrels breeds. Heart rate in younger age group (<2 years) dogs was significantly higher when compared to other age groups. Also, P (duration) and PR wave was significantly greater in geriatric dogs when compared to younger dogs.

Conflict of interest: The authors have no conflict of interest in this research paper.

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