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Electrocardiographic measurements in Santa Inês sheep

Medidas eletrocardiográficas em ovinos Santa Inês

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ABSTRACT: The absence of physiological normal values and electrocardiographic standards for clinically healthy sheep can hinder the detection of various conditions that might affect the transmission of cardiac impulses. This study aimed to determine the values of electrocardiographic measurements in leads D1, D2, D3, aVR, aVL, aVF, V1, V2, V3, and V4 and its correlation with the weight and age of sheep. The study was conducted with 39 nonpregnant and healthy Santa Inês sheep. They were categorized into four groups according to body weight: 7 sheep (20–30 kg), 14 sheep (30–40 kg), 11 sheep (40–50 kg), and 7 sheep (over 50 kg). They were also categorized into three groups according to age: 6 sheep (10–12 months), 28 sheep (16 and 17 months), and five sheep (2–4 years). Sheep aged 16 and 17 months showed a significant increase in P-wave time compared with sheep of other ages. There was no significant variation in terms of weight among the animals studied (P > 0.05). The reference intervals of electrocardiogram parameters did not show considerable variation in relation to weight and the age range from 10 months to 4 years. This corroborates the standardization of electrocardiographic normality values of non-sedated Santa Inês sheep.

KEYWORDS: animals; cardiology; reference values; ruminants.

RESUMO: A ausência de valores fisiológicos normais e padrões eletrocardiográficos para ovinos clinicamente saudáveis pode dificultar a detecção de diversas condições que podem afetar a transmissão dos impulsos cardíacos. Este estudo teve como objetivo determinar os valores das medidas eletrocardiográficas nas derivações D1, D2, D3, aVR, aVL, aVF, V1, V2, V3 e V4 e sua correlação com o peso e a idade dos ovinos. O estudo foi realizado com 39 ovelhas Santa Inês não gestantes e saudáveis. As ovelhas foram categorizadas em quatro grupos de acordo com o peso corporal: 7 ovelhas (20–30 kg), 14 ovelhas (30–40 kg), 11 ovelhas (40–50 kg) e 7 ovelhas (acima de 50 kg). Elas também foram categorizadas em três grupos de acordo com a idade: 6 ovelhas (10–12 meses), 28 ovelhas (16 e 17 meses) e cinco ovelhas (2–4 anos). Ovinos com 16 e 17 meses apresentaram aumento significativo no tempo da onda P em comparação com ovinos de outras idades. Não houve variação significativa em termos de peso entre os animais estudados (P > 0,05). Os intervalos de referência dos parâmetros do eletrocardiograma não apresentaram variação considerável em relação ao peso e à faixa etária de 10 meses a 4 anos. Isto corrobora a padronização dos valores de normalidade eletrocardiográficos de ovinos Santa Inês não sedados.

PALAVRAS-CHAVE: animais; cardiologia; valores de referência; ruminantes.

INTRODUCTION

During the last decade, there have been many improvements in the diagnosis of heart disease in sheep (*Ovis aries*) herds (Samimi *et al.*, 2016). Electrocardiography (ECG) is a complementary examination that is noninvasive, low-cost, and easy-to-perform. It allows for the detection of changes in the electrical conduction of the cardiac chambers and in the axis of the frontal plane (Camacho *et al.*, 2010). It is also a sensitive and specific technique for identifying cardiac arrhythmias and is widely used in veterinary medicine for domestic species (Nunes *et al.*, 2014).

The low number of diagnoses of structural cardiac abnormalities in sheep and goats may be because these animals are rarely presented for detailed medical evaluation (Hallowell; Potter; Bowen, 2012). However, sheep have been widely used in several experimental protocols, not only in veterinary medicine but also in human medicine, where they are considered an excellent experimental model (Alvites *et al.*, 2021; Do Nascimento *et al.*, 2022; Jousset *et al.*, 2012). This necessitates a more individualized approach for this species and the specific breed in question, as breed can considerably impact cardiac parameters (Ulian *et al.*, 2018).

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Specific waves are observed on ECG, representing the phases of depolarization (P, Q, R, and S waves) and repolarization (T wave) of the myocardium. These waves correspond to the contraction and relaxation of the cardiac chambers (ventricles). Following ventricular depolarization (QRS complex), the electrical plot typically returns to the baseline, forming the ST segment. This segment signifies the initial phase of ventricular repolarization and is examined for any elevation or depression relative to the baseline before the QRS complex. Such changes are often associated with electrolyte imbalances or myocardial ischemic processes. The duration of the QT interval is measured from the beginning of the Q wave to the end of the T wave, encompassing all ventricular electrical activity. This interval varies depending on the activity of the autonomic nervous system and inversely with heart rate. Ventricular repolarization occurs from the epicardial surface of the ventricle toward the endocardium, resulting in the electrocardiographic manifestation of the T wave (Mill, 2018).

For veterinarians, electrocardiographic reference values are essential for comparing the results of ill animals. The absence of normal reference values and electrocardiographic standards for clinically healthy sheep of a particular breed can hinder the detection of various conditions that might affect the transmission of cardiac impulses (Sudhakara; Sivajothi, 2018).

This study aimed to determine the values of electrocardiographic parameters and their relationship with the weight and age of nonpregnant, healthy, and non-sedated Santa Inês sheep. These values can serve as parameters for clinical evaluations and studies utilizing sheep as an experimental model.

MATERIAL AND METHODS

All experimental procedures performed in this study were submitted for evaluation and approved by the Ethics Committee on the Use of Animals under Opinion No. 8708221021. In addition to the guidelines established by the Ethics Committee above mentioned, the experiment also followed the ARRIVE guidelines described by Percie du Sert et al. (2020).

The inclusion criteria were healthy sheep aged between 10 months to 4 years, of the Santa Inês breed, and not pregnant. All sheep were subjected to clinical examination and blood count and fibrinogen tests before the study to confirm their healthy status. Animals with clinical and laboratory test results outside the normal range were excluded from the study. Moreover, sheep with abnormalities detected during cardiovascular examinations, such as valvular heart disease, hydropericardium, hydrothorax, deformation of the cardiac wall, inclusions in the cardiac cavities (whose origin was not the subject of further investigation), and turbulent blood flow inside the heart visible on echocardiography, were also excluded.

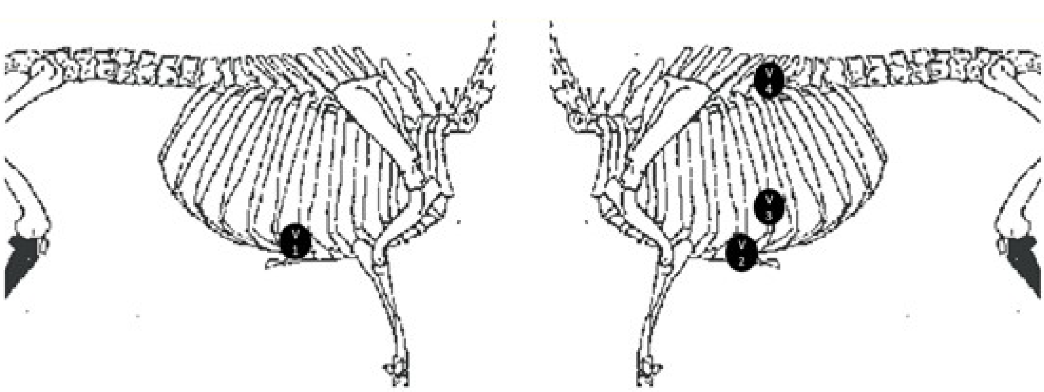
Thirty-nine adult Santa Inês sheep that met the inclusion criteria were selected at the Cardeiros Farm.

The sheep were separated from the herd and grouped in the management corral in the afternoon, starting an adaptation period of 90 minutes before the ECG evaluation. This evaluation was performed and recorded using an InPulse® ICV2.1 digital electrocardiograph with InCardio Duo 2.7.4 software (InPulse Animal Health, Florianópolis, Brazil).

The sheep were examined in a pen with a wooden floor acting as a contact insulator. The ECG was recorded with the animals in standing position and individually handled by their regular caretakers to minimize stress. None of the animals were sedated during the procedure.

The ECG recording lasted 2 minutes, considering the well-being of the non sedated animals and the quality of the electrocardiographic tracing. The electrodes were positioned according to the modified Lannek precordial derivation system for recording and interpreting the tracings (Detweiler; Patterson, 1965). Eight electrodes were applied, all of which were moistened with 70% alcohol: two in the axillary region of each front limb, two near the patella of each hind limb, and four in the precordial positions on the dorsum (as shown in Figure 1). This enabled the capture and recording of electrocardiographic plots and leads (D1, D2, D3, aVR, aVL, aVF, V1, V2, V3, and V4) at a speed of 50 mm/s, calibrated to 1 cm = 1 mV, for the evaluation of rhythm, electrical axis, and heart rate.

The electrocardiographic tracings obtained were interpreted from a randomly chosen electrocardiographic section



Source: SANTILLI et al., 2020.

Figure 1. Position of electrodes according to the modified Lannek precordial derivation system (DETWEILER; PATTERSON, 1965).

of the D2 lead without interference. This was done to perform a time evaluation (in milliseconds) of the P wave, PR interval, QRS complex, and QT segment, as well as to measure the amplitude (in millivolts) of waves P, Q, R, S, and T. Subsequently, the average electrical axis was calculated through vector analysis based on the polarity of the QRS complexes between the D1 and aVF leads, D2 and aVL leads, and D3 and aVR leads. The QT interval was corrected according to Framingham formula (Sagie *et al.*, 1992).

Numeric variables were analyzed using arithmetic means and standard deviations if they followed a normal distribution; otherwise, medians and interquartile deviations were used. The normality of the distribution was assessed using the Kolmogorov–Smirnov test. Reference intervals for the experimental population were determined as the average ± 2× standard deviations (Hallowell; Potter; Bowen, 2012). Body weight and age were compared using the Kruskal–Wallis test, with corrections made using the Student–Newman–Keuls test when necessary. A P-value of <0.05 was considered to indicate statistical significance. All analyses were performed using the BioEstat 5.3 program (Ayres *et al.*, 2017).

RESULTS

The animals were categorized into four groups according to body weight: 7 sheep (20–30 kg), 14 sheep (30–40 kg), 11 sheep (40–50 kg), and 7 sheep (over 50 kg). Subsequently, the same animals were divided into three groups according to age: 6 sheep (10–12 months), 28 sheep (16 and 17 months), and 5 sheep (2–4 years).

Among the 39 sheep examined, 30 (77%) had sinus rhythm and 9 (23%) had respiratory sinus arrhythmia, which is considered physiological and does not affect the examination or the animal's health. The ST wave interval was within a physiological value for the sheep species.

In the D2 derivation, the T-wave polarity was positive in 49% of the animals (19/39) and negative in 51% (20/39). In the V1 derivation, the T-wave polarity was positive in 54% (21/39) and negative in 46% (18/39). In the V4 derivation, the T-wave polarity was positive in 21% (8/39) and negative in 79% (31/39). Furthermore, in the V4 derivation, all animals exhibited QRS waves with a positive polarity.

Regarding the MEA, 21% (8/39) of the examinations showed an axis with left deviation (between −150° and −180°), whereas 69% (27/39) showed an axis with right deviation (between 150° and 180°). Among the 39 animals, 1 had an average electrical axis between −150° and 180°, while 3 had an axis between −90° and −120°.

Table 1 presents the reference intervals for the ECG parameters of the studied population, as well as a comparison of these parameters between groups with different weight ranges.

The sheep were also grouped according to age: 10–12 months (6/39), 16 and 17 months (28/39), and 2–4 years (5/39), as shown in Table 2.

Animals aged between 16 and 17 months showed a significant increase in P-wave time compared with animals of the other age groups in this study.

DISCUSSIONS

It is difficult to determine ECG values in sheep. Studies show that several factors that affect heart rate can alter ECG measurements in these animals, including breed, age, sex, stress, use of medication, the technique of data collection used, and different computerized ECG devices (Franco *et al.*, 2020; Koçkaya, 2019). According to Chiacchio *et al.* (2018), differences are found when comparing the conventional method with the computerized one. Thus, further research on this topic is needed (Koether *et al.*, 2016).

Sheep models are used in important areas of basic and translational cardiovascular research. And sheep have an advantage over pigs, as sheep cardiac myocytes have only 1 to 4 nuclei, thus being more similar to the human cardiomyocyte (Locatelli *et al.*, 2011). Furthermore, according to Rabbani *et al.* (2008) when studying sheep species anatomically, it was concluded that some anatomical and physiological structures were similar to human ones. In addition to the cardiac anatomy being similar to that of man, its anatomy allows easy access to the pulmonary and aortic valves (Kluin *et al.*, 2017; Lavinsky; Seibel, 2001).

According to Oliveira *et al.* (2008) the best results in relation to capturing electrocardiographic tracings in ruminants is the use of electrodes on all four limbs. This fact proves the theory of Tório *et al.* (1997) who stated Einthoven's principles for placing electrodes in sheep, with adequate anatomical positioning of the heart, generating less variation in the electrocardiographic tracing, improving the amplitude and correct evaluation of all parameters. As was done in the methodology of the present study. And as is done in humans, where there are several ways to position the electrodes for the ECG examination and the main bipolar montage is the Einthoven system (Schwarz, 2009).

Few ECG studies have been conducted in sheep. One of the earliest was conducted by Schultz; Pretorius; Terblanche (1972) with 31 animals of the Merino breed, one year old, weighing 36–49 kg, in the frontal plane derivations, with the animals in a quadrupedal position and without sedation. The conditions of that study were very similar to those in the present study, with the only difference being the breed of sheep studied. In that study, they determined the heart rate and the amplitude and duration of the P and T waves and the QRS complex. A major finding of that study was a variation in the P wave, which seems to be a normal feature of ECG in sheep (Schultz; Pretorius; Terblanche, 1972).

In the present study, sheep aged between 16 and 17 months showed a significant increase in the duration of the P wave compared with sheep of other age groups. A study by Chalmeh *et al.* (2015) in adult animals and lambs of the Chios

Table 1. Electrocardiographic measurement values for Santa Inês sheep grouped according to weight (N = 39).

Parameter (unit)	Population reference range (M ± 2× SD)	Sheep 20–30 kg M ± SD (amplitude)	Sheep >30–40 kg M ± SD (amplitude)	Sheep >40–50 kg M ± SD (amplitude)	Sheep >50 kg M ± SD (amplitude)	*P* value
N	39	7	14	11	7	
HR (bpm)	70 to 145 (107.6 ± 37.34)	103.43 ± 9.66 (86–111)	95.61 ± 13.77 (73–120)	99.36 ± 11.65 (86–125)	110.29 ± 26.91 (93–166)	0.4126
P (s)	0.01 to 0.05 (0.03 ± 0.02)	0.03 ± 0.01 (0.02–0.04)	0.03 ± 0.01 (0.02–0.04)	0.03 ± 0.01 (0.02–0.04)	0.03 ± 0.01 (0.02–0.04)	0.5210
PR (s)	0.1 to 0.14 (0.12 ± 0.02)	0.11 ± 0.01 (0.10–0.12)	0.11 ± 0.01 (0.10–0.14)	0.12 ± 0.02 (0.10–0.14)	0.13 ± 0.02 (0.10–0.14)	0.2225
QRS (mV)	0 to 0.51 (0.24 ± 0.27)	0.31 ± 0.16 (0.10–0.50)	0.22 ± 0.11 (0.10–0.50)	0.20 ± 0.13 (0.10–0.50)	0.26 ± 0.17 (0.10–0.50)	0.3968
QT (s)	0.18 to 0.32 (0.25 ± 0.07)	0.24 ± 0.04 (0.20–0.30)	0.26 ± 0.03 (0.22–0.30)	0.25 ± 0.02 (0.22–0.30)	0.26 ± 0.05 (0.18–0.34)	0.6138
QTc (s)	0.27 to 0.40 (0.32 ± 0.06)	0.30 ± 0.03 (0.27-0.36)	0.32 ± 0.02 (0.28-0.34)	0.31 ± 0.02 (0.27-0.35)	0.33 ± 0.04 (0.28-0.40)	00.6950
T (mV)	0.02 to 0.28 (0.15 ± 0.13)	0.13 ± 0.05 (0.10–0.20)	0.14 ± 0.06 (0.10–0.30)	0.16 ± 0.08 (0.10–0.30)	0.14 ± 0.05 (0.10–0.20)	0.8181
V1 R (mV)	0 to 0.28 (0.14 ± 0.14)	0.13 ± 0.05 (0.10–0.20)	0.16 ± 0.09 (0.10–0.40)	0.15 ± 0.05 (0.10–0.20)	0.13 ± 0.05 (0.10–0.20)	0.8636
V1 T (mV)	0.06 to 0.16 (0.11 ± 0.05)	0.10 ± 0.00 (0.10–0.10)	0.11 ± 0.03 (0.10–0.20)	0.10 ± 0.00 (0.10–0.10)	0.13 ± 0.05 (0.10–0.20)	0.1180
V2 R (mV)	0.03 to 0.21 (0.12 ± 0.09)	0.11 ± 0.04 (0.10–0.20)	0.11 ± 0.04 (0.10–0.20)	0.11 ± 0.03 (0.10–0.20)	0.14 ± 0.08 (0.10–0.30)	0.6815
V2 S (mV)	0.02 to 0.22 (0.12 ± 0.10)	0.10 ± 0.00 (0.10–0.10)	0.11 ± 0.04 (0.10–0.20)	0.15 ± 0.08 (0.10–0.30)	0.10 ± 0.00 (0.10–0.10)	0.2344
V3 R (mV)	0.04 to 0.18 (0.11 ± 0.07)	0.11 ± 0.04 (0.10–0.20)	0.10 ± 0.03 (0.10–0.20)	0.11 ± 0.03 (0.10–0.20)	0.13 ± 0.05 (0.10–0.20)	0.5613
V3 S (mV)	0.06 to 0.16 (0.11 ± 0.05)	0.10 ± 0.00 (0.10–0.10)	0.11 ± 0.03 (0.10–0.20)	0.11 ± 0.03 (0.10–0.20)	0.10 ± 0.00 (0.10–0.10)	0.7537
V4 QRS (mV)	0.16 to 0.46 (0.31 ± 0.15)	034 ± 0.10 (0.20–0.50)	0.29 ± 0.06 (0.20–0.40)	0.34 ± 0.08 (0.20–0.50)	0.29 ± 0.07 (0.20–0.40)	0.3230
V4 T (mV)	0.01 to 0.27 (0.14 ± 0.13)	0.11 ± 0.04 (0.10–0.20)	0.14 ± 0.08 (0.10–0.30)	0.16 ± 0.08 (0.10–0.30)	0.13 ± 0.05 (0.10–0.20)	0.4612

Different letters in the lines indicate a significant difference according to the Kruskal–Wallis test ($P < 0.05$). bpm: beats per minute; HR: heart rate; M: mean; N: total number of sheep; P: P wave; PR: interval between the P and R waves; QRS: QRS complex; QT: interval between the Q and T waves; QTc: interval between the Q and T waves corrected; R: R wave; S: S wave; SD: standard deviation; T: T wave.
There was no significant difference ($P > 0.05$) in the ECG parameters among the animals in terms of weight.

breed demonstrated that due to the smaller cardiac size and the presence of more superficial Purkinje fibers in lambs compared with adult sheep, there may be shorter duration intervals in younger animals. Studies suggest that as animals grow and the mass of their hearts increases, the duration of the transfer of cardiac electrical activity also increases (Schmidt Nielsen, 1997). This corroborates the findings in 16 and 17 month-old Santa Inês sheep when compared with younger animals.

The P-wave speed showed a statistically significant variation between different age groups, but it remained within the reference for the population. The P wave represents atrial depolarization and can be positive, negative, or biphasic. The presence of the P wave indicates sinus rhythm. The P wave is measured from the beginning to the end of the deflection. Changes in P-wave amplitude or duration suggest atrial overload, while the absence of the P wave with an irregular rhythm may indicate the presence of atrial fibrillation (Mill, 2018).

Several studies have reported that the durations of the P and T waves; the QRS complex; and the PR, QT, and ST intervals, as well as the amplitudes of the P and T waves, decrease as the heart rate increases (Koçkaya, 2019). Considering that the 16 and 17 month-old group of Santa Inês sheep in the present study had the highest heart rate amplitude, with a

Table 2. Electrocardiographic measurement values for Santa Inês sheep grouped according to age (N = 39).

Parameter (unit)	Population reference range (M ± 2× SD)	Sheep 10–12 months M ± SD (amplitude)	Sheep 16 and 17 months M ± SD (amplitude)	Sheep 2–4 years M ± SD (amplitude)	*P* value
N	39	6	28	5	
HR (bpm)	70 to 145 (107.6 ± 37.34)	109.42 ± 12.03 (95–131)	101.39 ± 18.24 (73–166)	97.20 ± 12.00 (83–111)	0.4954
P (s)	0.01 to 0.05 (0.03 ± 0.02)	0.02 ± 0.01[a] (0.02–0.04)	0.03 ± 0.01[b] (0.02–0.04)	0.02 ± 0.01[ab] (0.02–0.04)	0.0218
PR (s)	0.1 to 0.14 (0.12 ± 0.02)	0.11 ± 0.01 (0.10–0.12)	0.12 ± 0.01 (0.10–0.14)	0.12 ± 0.02 (0.10–0.14)	0.5159
QRS (mV)	0 to 0.51 (0.24 ± 0.27)	0.27 ± 0.10 (0.10–0.40)	0.24 ± 0.15 (0.10–0.50)	0.20 ± 0.00 (0.20–0.20)	0.5582
QT (s)	0.18 to 0.32 (0.25 ± 0.07)	0.25 ± 0.04 (0.20–0.30)	0.25 ± 0.03 (0.18–0.30)	0.28 ± 0.05 (0.22–0.34)	0.2911
QTc (s)	0.27 to 0.40 (0.32 ± 0.06)	0.31 ± 0.03 (0.27-0.36)	0.31 ± 0.02 (0.27-0.36)	0.34 ± 0.04 (0.29-0.40)	0.3139
T (mV)	0.02 to 0.28 (0.15 ± 0.13)	0.12 ± 0.04 (0.10–0.20)	0.16 ± 0.07 (0.10–0.30)	0.10 ± 0.00 (0.10–0.10)	0.0565
V1 R (mV)	0 to 0.28 (0.14 ± 0.14)	0.12 ± 0.04 (0.10–0.20)	0.15 ± 0.07 (0.10–0.40)	0.12 ± 0.05 (0.10–0.20)	0.3307
V1 T (mV)	0.06 to 0.16 (0.11 ± 0.05)	0.10 ± 0.00 (0.10–0.10)	0.11 ± 0.03 (0.10–0.20)	0.10 ± 0.00 (0.10–0.10)	0.5369
V2 R (mV)	0.03 to 0.21 (0.12 ± 0.09)	0.10 ± 0.00 (0.10–0.10)	0.13 ± 0.05 (0.10–0.30)	0.10 ± 0.00 (0.10–0.10)	0.2588
V2 S (mV)	0.02 to 0.22 (0.12 ± 0.10)	0.10 ± 0.00 (0.10–0.10)	0.13 ± 0.06 (0.10–0.30)	0.10 ± 0.00 (0.10–0.10)	0.3353
V3 R (mV)	0.04 to 0.18 (0.11 ± 0.07)	0.10 ± 0.00 (0.10–0.10)	0.12 ± 0.04 (0.10–0.20)	0.10 ± 0.00 (0.10–0.10)	0.3336
V3 S (mV)	0.06 to 0.16 (0.11 ± 0.05)	0.10 ± 0.00 (0.10–0.10)	0.11 ± 0.03 (0.10–0.20)	0.10 ± 0.00 (0.10–0.10)	0.6680
V4 QRS (mV)	0.16 to 0.46 (0.31 ± 0.15)	0.33 ± 0.10 (0.20–0.50)	0.31 ± 0.07 (0.20–0.50)	0.30 ± 0.07 (0.20–0.40)	0.8562
V4 T (mV)	0.01 to 0.27 (0.14 ± 0.13)	0.12 ± 0.04 (0.10–0.20)	0.15 ± 0.08 (0.10–0.30)	0.10 ± 0.00 (0.10–0.10)	0.2045

Different letters in the lines indicate a significant difference according to the Kruskal–Wallis test ($P < 0.05$). bpm: beats per minute; HR: heart rate; M: mean; N: total number of sheep; P: P wave; PR: interval between the P and R waves; QRS: QRS complex; QT: interval between the Q and T waves; QTc: interval between the Q and T waves corrected; R: R wave; S: S wave; SD: standard deviation; T: T wave.

maximum value of 166 beats per minute, this corroborates the findings of those studies.

Significant differences in the heart rate, amplitude of ECG waves (including the QRS complex and T wave), and duration of PR, QT, and RR intervals were observed between the age groups in the present study. The heart rate gradually decreases with aging (Sudhakara; Sivajothi, 2018). The average heart rate of Santa Inês sheep aged >2 years in the present study was also lower than that of younger sheep.

The QT interval represents the phases of depolarization and repolarization of the ventricular myocardium. It is measured from the beginning of the QRS complex to the end of the T wave. The QT interval varies with the heart rate, the lower the heart rate, the longer the QT interval. Therefore, this interval must be corrected using formulas that consider the heart rate and the RR interval. These correction formulas were developed in human studies (Santilli *et al.*, 2020). In the present study, there was no significant difference between the weight and age groups in relation to the corrected QT interval (QTc). This may indicate a normal value of this parameter for healthy Santa Inês sheep. Generally, QTc varies in heart disease or intoxication. However, as demonstrated in the study by Lago *et al.* (2009) and Koyama *et al.* (2004) discrete degrees of intoxication do not increase QTc, as the increase in heart rate masks this parameter in these cases.

In the present study, with non-sedated, healthy sheep in a normal physiological situation, the T wave was predominantly negative. In the study by Lago *et al.* (2009), the T wave was biphasic or positive, and the positive form was predominant after physical exercise in all animals. Other authors also described the variation occurring in the T wave, which appears to be a normal characteristic of the sheep electrocardiogram, admitting these two morphologies without necessarily indicating disease (Schultz *et al.*, 1972; Tório *et al.*, 1997; Ker *et al.*, 2003).

CONCLUSIONS

It can be concluded that the reference intervals of electrocardiogram parameters did not exhibit any considerable variation in terms of the age range studied (10 months–4 years) and weight. This corroborates the standardization of normal electrocardiographic values for non-sedated Santa Inês sheep. Because sheep are experimental animals in human and veterinary cardiology, defining the values of electrocardiographic measurements is essential for the accuracy of examinations and research.

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