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IMPACT OF OBESITY ON ECHOCARDIOGRAPHIC AND ELECTROCARDIOGRAPHIC EVALUATION IN DOGS

IMPACTO DA OBESIDADE NA AVALIAÇÃO ECOCARDIOGRÁFICA E ELETROCARDIOGRÁFICA EM CÃES

IMPACTO DE LA OBESIDAD EN LA EVALUACIÓN ECOCARDIOGRÁFICA Y ELECTROCARDIOGRÁFICA EN PERROS

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ABSTRACT

Canine obesity is an increasingly prevalent multifactorial condition that may cause cardiovascular dysfunction before overt heart disease becomes clinically apparent. This study evaluated the impact of obesity on echocardiographic and electrocardiographic parameters in dogs, with emphasis on hemodynamic, electrical, and diastolic changes. A comparative cross-sectional case-control study included 30 adult dogs, equally allocated to a control group with ideal body condition score (BCS 4–5/9) and an obese group (BCS 8–9/9). Systolic blood pressure (SBP), electrocardiography, and transthoracic echocardiography were performed under standardized conditions. Obese dogs had significantly higher SBP, heart rate, and corrected QT interval. Echocardiography revealed mildly increased left atrium-to-aorta ratio, reduced tissue Doppler e' velocity, increased E/e' ratio, and a mild increase in left ventricular posterior wall thickness, suggesting early diastolic dysfunction with preserved systolic function. Hypertension and isolated ventricular premature complexes were more frequent in obese dogs but were not statistically significant as categorical outcomes. Canine obesity was associated with measurable subclinical cardiovascular alterations. Routine blood-pressure monitoring and individualized assessment of diastolic echocardiographic indices, alongside early body-weight management, may help mitigate cardiovascular risk in obese dogs.

KEYWORDS: *Dogs. Echocardiography. Electrocardiography. Obesity. Blood pressure. Cardiovascular system.*

RESUMO

A obesidade canina é uma condição multifatorial cada vez mais prevalente, capaz de ocasionar disfunção cardiovascular antes que a cardiopatia manifesta se torne clinicamente evidente. Este estudo avaliou o impacto da obesidade sobre parâmetros ecocardiográficos e eletrocardiográficos em cães, com ênfase nas alterações hemodinâmicas, elétricas e diastólicas.

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Um estudo comparativo, transversal, do tipo caso-controle, incluiu 30 cães adultos, distribuídos igualmente em grupo controle, com escore de condição corporal ideal (ECC 4–5/9), e grupo obeso (ECC 8–9/9). A pressão arterial sistólica (PAS), a eletrocardiografia e a ecocardiografia transtorácica foram realizadas em condições padronizadas. Os cães obesos apresentaram PAS, frequência cardíaca e intervalo QT corrigido significativamente maiores. A ecocardiografia revelou discreto aumento da relação átrio esquerdo/aorta, redução da velocidade e' ao Doppler tecidual, aumento da relação E/e' e leve aumento da espessura da parede posterior do ventrículo esquerdo, sugerindo disfunção diastólica inicial com função sistólica preservada. Hipertensão e complexos ventriculares prematuros isolados foram mais frequentes nos cães obesos, porém sem significância estatística como desfechos categóricos. A obesidade canina associou-se a alterações cardiovasculares subclínicas mensuráveis. O monitoramento rotineiro da pressão arterial e a avaliação individualizada dos índices ecocardiográficos diastólicos, aliados ao manejo precoce do peso corporal, podem contribuir para reduzir o risco cardiovascular em cães obesos.

PALAVRAS-CHAVE: Cães. Ecocardiografia. Eletrocardiografia. Obesidade. Pressão arterial. Sistema cardiovascular.

RESUMEN

La obesidad canina es una condición multifactorial cada vez más prevalente que puede causar disfunción cardiovascular antes de que una cardiopatía manifiesta sea clínicamente evidente. Este estudio evaluó el impacto de la obesidad sobre los parámetros ecocardiográficos y electrocardiográficos en perros, con énfasis en los cambios hemodinámicos, eléctricos y diastólicos. Se realizó un estudio comparativo, transversal, de casos y controles, que incluyó 30 perros adultos, distribuidos por igual en un grupo control con puntuación de condición corporal ideal (PCC 4–5/9) y un grupo obeso (PCC 8–9/9). La presión arterial sistólica (PAS), la electrocardiografía y la ecocardiografía transtorácica se realizaron en condiciones estandarizadas. Los perros obesos presentaron PAS, frecuencia cardíaca e intervalo QT corregido significativamente mayores. La ecocardiografía reveló un ligero aumento de la relación aurícula izquierda/aorta, reducción de la velocidad e' mediante Doppler tisular, aumento de la relación E/e' y leve incremento del grosor de la pared posterior del ventrículo izquierdo, lo que sugiere disfunción diastólica temprana con función sistólica preservada. La hipertensión y los complejos ventriculares prematuros aislados fueron más frecuentes en los perros obesos, pero no alcanzaron significación estadística como resultados categóricos. La obesidad canina se asoció con alteraciones cardiovasculares subclínicas mensurables. El control rutinario de la presión arterial y la evaluación individualizada de los índices ecocardiográficos diastólicos, junto con el manejo temprano del peso corporal, pueden contribuir a reducir el riesgo cardiovascular en perros obesos.

PALABRAS CLAVE: *Perros. Ecocardiografía. Electrocardiografía. Obesidad. Presión arterial. Sistema cardiovascular.*

INTRODUCTION

Canine obesity is increasingly recognized as a cardiovascular modifier, but the extent to which clinically stable obese dogs already exhibit subclinical hemodynamic, electrical, and structural changes remains incompletely characterized. The research problem addressed in this study was whether adult dogs with a body condition score of 8–9/9, without clinically relevant primary cardiac or pulmonary disease, present measurable cardiovascular alterations compared with dogs with an ideal body condition score.

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The study is justified by the possibility that cardiovascular abnormalities associated with excess adiposity may precede overt heart disease and remain undetected during routine physical examination. Early recognition of these changes may support more appropriate cardiovascular monitoring and reinforce timely weight-management strategies in clinical practice (Laflamme, 2006; Partington *et al.*, 2022).

The general objective was to compare systolic blood pressure, electrocardiographic variables, and echocardiographic indices of cardiac structure and function between obese dogs and dogs with ideal body condition. The specific objectives were to evaluate heart rate and ventricular repolarization, investigate the frequency of hypertension and arrhythmias, assess left atrial and ventricular diastolic indices, and determine whether conventional left- and right-ventricular systolic function remained preserved.

1. THEORETICAL FRAMEWORK

Canine obesity is a prevalent nutritional disorder in companion animal medicine and is associated with endocrine, orthopedic, respiratory, and cardiovascular consequences. Excess adiposity can promote neurohormonal activation, autonomic imbalance, increased blood pressure, and greater myocardial workload, thereby contributing to cardiac remodeling (Laflamme, 2006; Partington *et al.*, 2022).

Cardiovascular abnormalities in obese dogs may be mild and undetectable on routine physical examination. Electrocardiography and echocardiography are therefore useful for identifying early changes in ventricular filling, atrial remodeling, myocardial wall thickness, and ventricular repolarization (Pereira-Neto *et al.*, 2010; Dittrich *et al.*, 2018).

Previous studies have reported obesity-associated changes in blood pressure, autonomic regulation, and cardiac structure, with evidence that controlled weight reduction may improve some cardiovascular indices. Because individual echocardiographic measurements are influenced by body size and loading conditions, integrated interpretation of left atrial size, tissue Doppler indices, conventional systolic variables, and right-ventricular measurements is recommended (Pariaut *et al.*, 2012; Chetboul *et al.*, 2018; Visser *et al.*, 2015; Pongkan *et al.*, 2020). Recent evidence has further strengthened the clinical rationale for integrated monitoring. A systematic review identified increased body weight and left atrial enlargement as relevant risk factors for atrial fibrillation in dogs with underlying cardiac disease, while a meta-analysis supported structured hypocaloric dietary strategies for canine weight loss and preservation of lean body mass. A recent clinical study also documented early electrocardiographic and left atrial changes in overweight and obese dogs (Arcuri *et al.*, 2024; Vanelli *et al.*, 2025; Silva *et al.*, 2026).

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2. METHODOLOGY

Study design and animals

This observational, cross-sectional, case-control study was conducted at the outpatient clinic and diagnostic imaging sector of Universidade de Vassouras. The protocol was approved by the Animal Use Ethics Committee (CEUA), protocol no. 058/2024. All owners signed an informed consent form.

Thirty adult client-owned dogs were included and equally assigned to a control group (GCt; BCS 4–5/9) or obese group (GOb; BCS 8–9/9). Dogs were consecutively recruited from the outpatient clinical routine, forming a pragmatic clinical sample that reflected the heterogeneity commonly encountered in practice. Inclusion criteria were age between 2 and 8 years, either sex, and no clinically relevant primary cardiac or pulmonary disease. Animals with active systemic disease, sustained arrhythmia, severe hypertension with target-organ damage, recent use of drugs that could alter heart rate or blood pressure, or inadequate echocardiographic windows were excluded. Both sexes and different breeds and body sizes were accepted; sex and breed were not used as matching or stratification variables.

The examination sequence was standardized as acclimatization, blood pressure measurement, electrocardiography, and echocardiography. All acquisitions and measurements were performed by a single experienced operator blinded to group allocation.

Clinical, electrocardiographic, and echocardiographic assessment

Systolic blood pressure was measured by a validated oscillometric method, with Doppler confirmation when readings were inconsistent. Five measurements were obtained after acclimatization; the first was discarded, and the mean of the remaining four measurements was used. Hypertension was defined as SBP ≥ 140 mmHg (Acierno *et al.*, 2018).

Six-lead electrocardiography was recorded at 50 mm/s and 10 mm/mV in right lateral recumbency. Mean heart rate, PR, QRS, QT, corrected QT interval (QTc), electrical axis, and arrhythmias were evaluated. Transthoracic echocardiography included LA/Ao, interventricular septal thickness in diastole (IVSd), left ventricular posterior wall thickness in diastole (LVPWd), fractional shortening, tricuspid annular plane systolic excursion (TAPSE), fractional area change (FAC), systolic myocardial velocity (S'), tissue Doppler e' velocity, E/e', pulmonary flow velocity, and estimated transpulmonary gradient. Interpretation of right ventricular indices considered body-size influence (Pariaut *et al.*, 2012; Chetboul *et al.*, 2018; Visser *et al.*, 2015).

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Statistical analysis

Primary outcomes were SBP, LA/Ao, e', and E/e'. Secondary outcomes included heart rate, QTc, TAPSE, FAC, S', IVSd, LVPWd, pulmonary flow velocity, transpulmonary gradient, hypertension, and arrhythmias. The sample size was defined pragmatically according to clinical feasibility and sample sizes used in previous exploratory studies of canine obesity (Pereira-Neto *et al.*, 2010; Pongkan *et al.*, 2020; Partington *et al.*, 2022). Accordingly, the present investigation should be interpreted as an exploratory pilot study; no formal a priori power calculation was performed. Data were analyzed in BioEstat 5.3®. Normality, outliers, and homoscedasticity were assessed by the Shapiro–Wilk, Dixon, and Levene tests. Continuous variables were compared by two-tailed Welch t test or Mann–Whitney test, as appropriate. Categorical variables were compared by Fisher's exact test, with odds ratio and 95% confidence interval when applicable. Significance was set at 5%. Owing to the modest sample size and the risk of overfitting, multivariable models were not fitted.

3. RESULTS AND DISCUSSION

3.1. Results

Thirty dogs were analyzed, with 15 animals in each group. Age was similar between groups, whereas body weight was greater in obese dogs, as expected by the group allocation criterion (Table 1).

Table 1. Demographic and baseline characteristics by group (GCt vs. GOb; mean ± standard deviation; n = 15 per group)

Characteristic	GCt (n = 15)	GOb (n = 15)	Observation
Age (years)	5.9 ± 2.1	6.2 ± 2.0	Age-matched groups
Body weight (kg)	18.2 ± 6.1	28.4 ± 7.3	Higher in GOb
BCS (9-point scale)	4–5/9	8–9/9	Allocation criterion
Age range (years)	2–8	2–8	Identical between groups
Sex	Both sexes represented	Both sexes represented	Not used for stratification

BCS: body condition score. Values are mean ± standard deviation. Source: Study data (2026).

Obese dogs showed significantly higher SBP, heart rate, and QTc than controls. The effect magnitude was large for body weight and SBP and moderate to large for the remaining significant variables (Table 2 and Figure 1).

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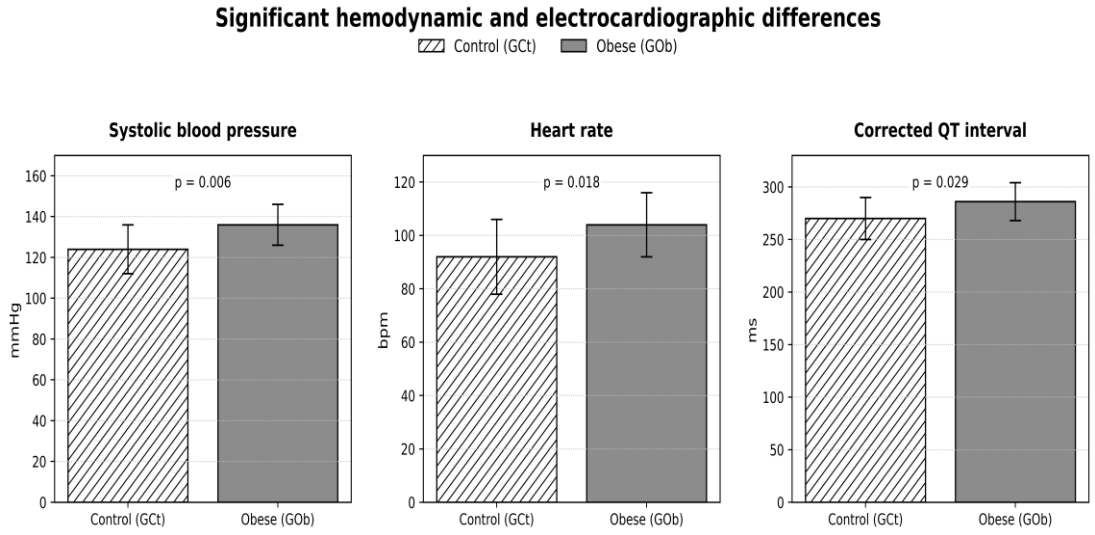
Table 2. Continuous variables and between-group comparison (n = 15 per group).

Variable	GCt	GOb	Difference (GOb − GCt)	p	Hedges' g
Age (years)	5.9 ± 2.1	6.2 ± 2.0	+0.30	0.692	0.14
Body weight (kg)	18.2 ± 6.1	28.4 ± 7.3	+10.20	< 0.001	1.48
SBP (mmHg)	124 ± 12	136 ± 10	+12.00	0.006	1.06
Heart rate (bpm)	92 ± 14	104 ± 12	+12.00	0.018	0.90
QTc (ms)	270 ± 20	286 ± 18	+16.00	0.029	0.82

Values are mean ± standard deviation. SBP: systolic blood pressure; HR: heart rate; QTc: corrected QT interval; 95% CI: 95% confidence interval. Statistical testing used the two-tailed Welch t test. Source: Study data (2026).

Figure 1. Statistically significant hemodynamic and electrocardiographic differences between control and obese dogs. Bars represent mean ± standard deviation. Abbreviations: SBP, systolic blood pressure; QTc, corrected QT interval.



Source: Study data (2026).

Hypertension and isolated ventricular premature complexes were more frequent in obese dogs, but the categorical comparisons did not reach statistical significance and showed wide confidence intervals (Table 3).

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Table 3. Categorical outcomes by group (n = 15 per group)

Outcome	GCt (n/N; %)	GOb (n/N; %)	OR	95% CI	Test	p
Hypertension (SBP ≥ 140 mmHg)	2/15 (13.3%)	6/15 (40.0%)	4.33	0.71–26.53	Fisher	0.215
Isolated ventricular premature complexes	0/15 (0.0%)	3/15 (20.0%)	8.68*	0.41–184.29*	Fisher	0.224

* Odds ratio and 95% CI were estimated using Haldane–Anscombe correction because of a zero cell. Abbreviations: OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure. Source: Study data (2026).

Echocardiography showed a pattern consistent with early diastolic dysfunction in obese dogs: LA/Ao and E/e' were higher, while e' was lower. LVPWd was also mildly increased. Systolic function remained preserved (Tables 4 and 5; Figures 2 and 3).

Table 4. Echocardiographic indices of diastolic function and remodeling in control and obese dogs

Variable	GCt	GOb	Test	p	Interpretation
LA/Ao	1.31 ± 0.09	1.39 ± 0.12	Welch	0.045	Mild increase in atrial load
e' TDI (cm/s)	11.2 ± 1.8	9.8 ± 1.7	Welch	0.037	Reduced relaxation
E/e'	6.6 ± 1.2	8.1 ± 1.4	Welch	0.004	Increased filling pressure
FS (%)	37.1 ± 4.2	36.4 ± 4.5	Welch	0.660	Preserved systolic function
IVSd (mm)	6.8 ± 1.0	7.3 ± 1.1	Welch	0.200	Trend toward wall thickening
LVPWd (mm)	6.7 ± 1.0	7.6 ± 1.2	Welch	0.034	Mild posterior-wall thickening

Abbreviations: LA/Ao, left atrium-to-aorta ratio; TDI, tissue Doppler imaging; FS, fractional shortening; IVSd, interventricular septal thickness in diastole; LVPWd, left ventricular posterior wall thickness in diastole. Values are mean ± standard deviation. Source: Study data (2026).

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Figure 2. Statistically significant echocardiographic differences between control and obese dogs. Bars represent mean ± standard deviation. Abbreviations: LA/Ao, left atrium-to-aorta ratio; TDI, tissue Doppler imaging; LVPWd, left ventricular posterior wall thickness in diastole.

Source: Study data (2026).

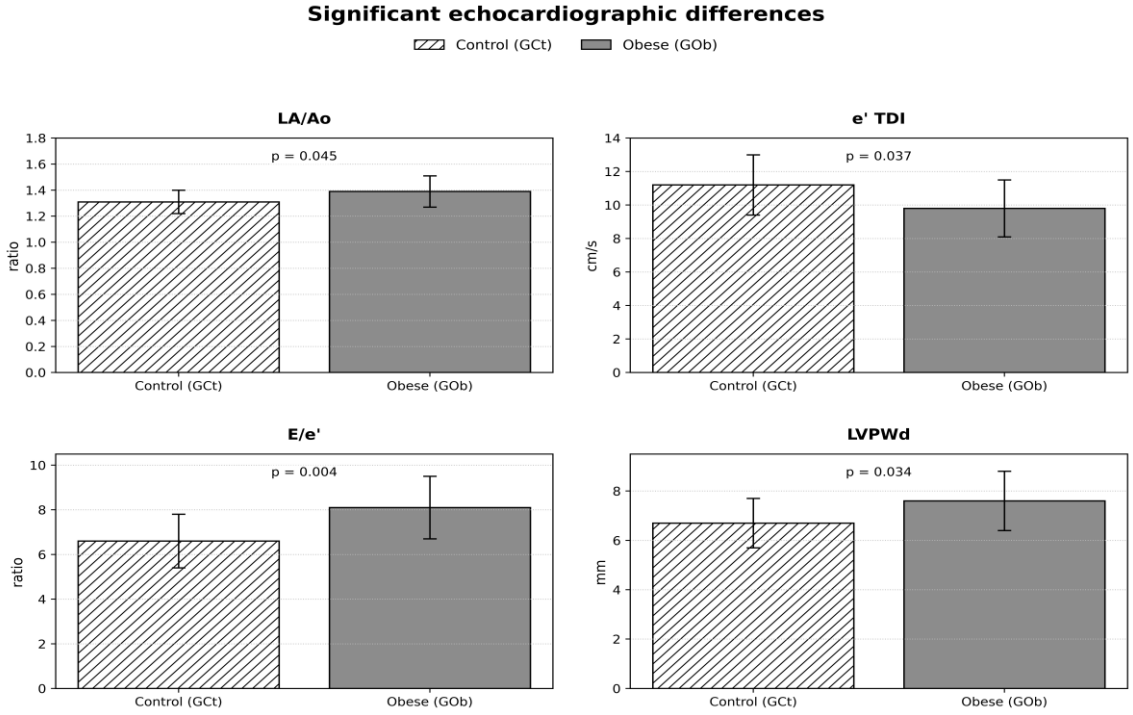

Table 5. Right ventricular function and pulmonary hemodynamics in control and obese dogs

Variable	GCt	GOb	Test	p	Interpretation
TAPSE (mm)*	11.7 ± 1.8	11.4 ± 1.9	Welch	0.660	Within expected range
FAC (%)	44.1 ± 6.3	43.2 ± 6.0	Welch	0.690	Preserved
S' TDI (cm/s)	11.8 ± 1.6	11.5 ± 1.7	Welch	0.620	Preserved
Pulmonary flow velocity (m/s)	0.92 ± 0.15	0.95 ± 0.17	Welch	0.540	No pulmonary hypertension
Transpulmonary gradient (mmHg)	3.4 ± 1.0	3.6 ± 1.2	Welch	0.520	No pulmonary hypertension

Abbreviations: TAPSE, tricuspid annular plane systolic excursion; FAC, fractional area change; TDI, tissue Doppler imaging. * TAPSE was interpreted considering body-size adjustment. Values are mean ± standard deviation. Source: Study data (2026).

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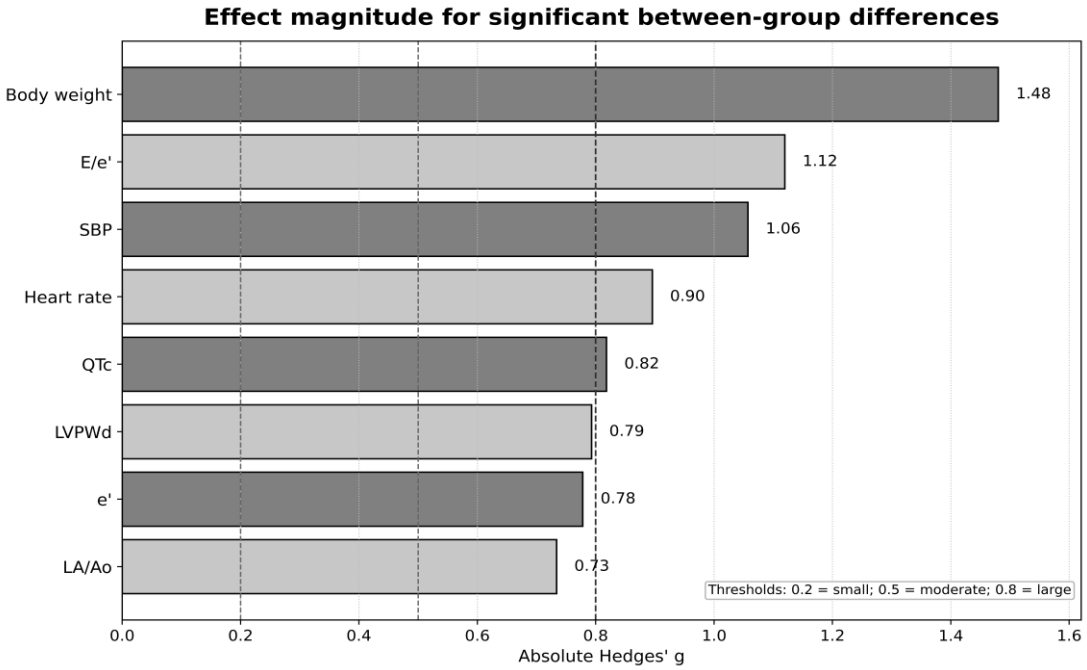
Figure 3. Effect magnitude, expressed as absolute Hedges' g, for variables with statistically significant between-group differences. Dashed vertical lines indicate conventional thresholds for small (0.2), moderate (0.5), and large (0.8) effects.



Source: Study data (2026).

3.2. Discussion

The present findings indicate that obesity in dogs is associated with a coherent cluster of hemodynamic, electrical, and echocardiographic alterations. Obese dogs had higher systolic blood pressure (SBP), resting heart rate, and corrected QT interval (QTc), together with increased LA/Ao and E/e' and reduced e' velocity. The coexistence of these changes despite preserved conventional systolic indices supports a predominantly subclinical cardiovascular burden, rather than overt systolic failure. Therefore, excess adiposity should be regarded as a clinically relevant cardiovascular modifier, even when no structural heart disease is detected during routine screening (Laflamme, 2006; Silva *et al.*, 2026).

The increase in SBP is biologically plausible and consistent with the multifactorial pathophysiology of obesity. Excess adiposity may contribute to neurohormonal activation, increased systemic vascular load, altered sodium handling, and cardiac remodeling, all of which can favor higher arterial pressure and myocardial workload (Acierno *et al.*, 2018; Borges *et al.*, 2016; Laflamme, 2006). The concurrent increase in resting heart rate further suggests altered autonomic regulation rather than an isolated pressor response. Although the direction and magnitude of heart-rate variability changes can differ among canine populations, autonomic

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impairment has been reported in obese dogs and has also been investigated during weight-loss programs (Pongkan *et al.*, 2020; Santos Filho *et al.*, 2019).

The diastolic findings deserve particular attention. A higher LA/Ao ratio and E/e' ratio occurring together with lower e' velocity provide stronger evidence of impaired ventricular relaxation and increased filling pressure than any single variable alone. Similar structural and functional changes have been reported in obese dogs, and controlled weight reduction may improve at least part of the obesity-associated cardiac remodeling (Pereira-Neto *et al.*, 2010; Partington *et al.*, 2022; Silva *et al.*, 2026). Nevertheless, LA/Ao should not be interpreted in isolation because atrial enlargement may be classified differently by linear and volumetric methods. Its value is therefore greatest when integrated with tissue Doppler and transmitral flow indices, as performed in this study (Wesselowski *et al.*, 2014).

The maintenance of fractional shortening, TAPSE, FAC, and S' within expected ranges suggests that the cardiovascular consequences observed here were predominantly diastolic and hemodynamic at the time of assessment. This interpretation should remain cautious because right ventricular indices are influenced by body size, imaging plane, loading conditions, and measurement repeatability. The combined use of TAPSE, FAC, and tissue Doppler-derived S' is consequently preferable to reliance on a single right ventricular systolic variable (Pariaut *et al.*, 2012; Chetboul *et al.*, 2018; Visser *et al.*, 2015).

QTc prolongation in the obese group may represent an early marker of altered ventricular repolarization. Direct evidence linking obesity to QTc prolongation in dogs remains limited; however, electrical abnormalities have been described in obese canine populations, and human studies consistently associate adiposity and metabolic dysfunction with QTc prolongation and greater arrhythmic susceptibility (Dittrich *et al.*, 2018; Patel *et al.*, 2022; Dykiert *et al.*, 2024). A recent systematic review identified increased body weight and left atrial enlargement as risk factors for atrial fibrillation in dogs with underlying cardiac disease, but these findings should not be directly extrapolated to otherwise clinically stable obese dogs (Arcuri *et al.*, 2024). The greater frequency of isolated ventricular premature complexes in obese dogs was not statistically significant in this small sample. Therefore, the present findings do not support routine Holter monitoring based solely on obesity; ambulatory electrocardiography is more appropriately considered when resting ECG reveals ectopy or when syncope, episodic weakness, unexplained tachycardia, or other clinical suspicion of intermittent arrhythmia is present. Larger studies incorporating 24-hour Holter monitoring and longitudinal assessment are needed to determine whether obesity independently increases arrhythmic burden.

From a clinical perspective, the findings support routine body-condition scoring, repeated blood-pressure measurements, and early institution of a structured weight-management plan in overweight and obese dogs (Acierno *et al.*, 2018; Vanelli *et al.*, 2025). Echocardiography may be

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considered when obesity is marked or persistent, when hypertension is confirmed, or when a murmur, exercise intolerance, respiratory signs, an abnormal resting ECG, or other cardiovascular risk factors are present. Nevertheless, this cross-sectional pilot study does not establish an evidence-based interval for annual echocardiography and does not justify systematic Holter monitoring in all obese dogs. Follow-up frequency should be individualized according to clinical findings, progression of adiposity, and response to weight reduction.

This study benefits from balanced groups, standardized examination conditions, and assessment by a single blinded operator, which strengthen internal consistency. However, its cross-sectional design precludes causal inference. The sample size was modest and was not based on a formal a priori power analysis, limiting precision and statistical power for categorical outcomes. Breed, body size, and sex were not matching or stratification variables, and the study was not powered for subgroup analyses. The absence of multivariable modeling means that residual confounding by age, sex, breed, body size, and unmeasured metabolic factors cannot be excluded. Laboratory biomarkers were not included in the present analysis and could help explain part of the hemodynamic and electrical findings in future studies. Prospective investigations should evaluate whether structured weight loss reverses the observed changes and should combine serial blood-pressure measurements, echocardiography, Holter-derived heart-rate variability, cardiac biomarkers, and metabolic profiles. Such designs may clarify which alterations are reversible and which identify dogs at increased long-term cardiovascular risk (Partington *et al.*, 2022; Santos Filho *et al.*, 2019; Silva *et al.*, 2026).

4. FINAL CONSIDERATIONS

Obese dogs showed significantly higher systolic blood pressure, heart rate, and QTc than control dogs with ideal body condition. Echocardiography showed preserved systolic function accompanied by early diastolic changes, particularly increased LA/Ao and E/e' and reduced e'.

Routine clinical assessment of obese dogs should prioritize repeated blood-pressure measurements, careful cardiovascular examination, and early, structured weight-management strategies. Echocardiographic assessment of diastolic indices may be considered in dogs with marked or persistent obesity or additional clinical abnormalities. Current findings are insufficient to recommend a fixed annual echocardiographic schedule or routine Holter monitoring solely because of obesity; ambulatory ECG should be guided by symptoms or resting ECG abnormalities.

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