Acta Scientiae Veterinariae, 2018. 46: 1586.

RESEARCH ARTICLE
Pub. 1586

ISSN 1679-9216

Effects of Different Heart Dimensions on Race Performance in Thorougbred Race Horses

Orhan Pınar[1] & Aziz Arda Sancak[2]

ABSTRACT

***Background*:** Athletic superiority could be present in horses with a specific cardiac phenotype that differs between race types. Measurement of chamber dimensions is considered one of the most important tools for assessing heart disease severity and prognosis as well as for evaluating cardiac responses to training and detraining. The purpose of this study was to evaluate the changes of cardiac dimensions and pathological finding in intensive exercise of Thoroughbred horses on their race performance by using the 2-D Doppler and M-Mode echocardiography according to their age, body weight and sex.

***Materials, Methods & Results*:** Thoroughbred horses (40 females and 40 males) in the facilities, Ankara and Istanbul of Racetract, of Jockey Club of Turkey were included in the study. Horses were assigned as 4 study groups according to their ages and body weight separately. Group IV and I non-race horses were >7 year-old and >490 kg, >1 to ≤2 and ≤ 390 kg, Group II and III race horses were >2 to ≤3 and >390 kg to ≤ 440 kg, >3 to ≤6 year-old and >440 kg to ≤490 kg, respectively. Intensive exercise was applied to horses except group IV. The relationships between selected echocardiographic variables according to horse age, body weight and sex were analysed. Specifically left ventricle (LV) assessment by diameter in systole and diastole (LVDd and LVDs) and posterior wall thickness (LVWs and LVWd), interventricular septal thickness (IVSd and IVSs), ejection fraction (EF), fractional shortening (FS), Stroke Volume (SV), cardiac output (CO) and left ventricle mass (LVM) were determined. Descriptive statistical analyses, including mean and standard deviation were used to summarise the data. Significant differences of LVDd ($P < 0.001$), LVDs ($P < 0.001$) and SV ($P < 0.001$) were only determined in group I compared to group IV non-race horses. Significant differences in values of CO ($P < 0.001$) was determined in group III compared to group II race horses, which shows the eccentric left ventricle hypertrophy developed in Thoroughbred horses during years of racing, especially more than 4 years old of intensive exercise. Present study indicated that linear relationships between echocardiographic variables and age ($P < 0.001$) and body weight ($P < 0.001$) were found, with the linear relationships between echocardiographic variables and age being stronger than those with body weight.

***Discussion*:** Relationships between echocardiographic measurements and body weight (BW) seem to be stronger than those with age. In horses, the effects of training and growth on echocardiographic measurements have been documented, and the influence of breed has been suggested by several authors. Also, it has been demonstrated that an eccentric cardiac hypertrophy occurs in response to race training attributable to an increased diastolic stress and thus, higher heart chambers are expected in the trained Thoroughbreds and Standardbreds horses. The lack of significant differences between age groups in several LV performance indices, such as FS% and EF% might indicate that the values reported here can be extrapolated to Thorougbred horses of different ages and BW. The homogeneity of racehorse management and their closed breeding population should allow unique insights into the subtle differences in cardiac adaptations that might be associated with small differences in training horses for different race disciplines.

Keywords: race horse, ages, body weight, echocardiography.

http://dx.doi.org/10.22456/1679-9216.84209

Received: 15 March 2018 Accepted: 19 July 2018 Published: 15 September 2018

[1]Jockey Club of Turkey, Ankara 75th year Race Track, Ankara, Turkey. [2]Ankara University, Faculty of Veterinary Medicine, Department of Internal Diseases, Ankara. CORRESPONDENCE: O. Pınar [vetorhanpinar@gmail.com - Tel.: +905324543451]. Jockey Club of Turkey, Ankara 75th year Race Track. 06374 Yenimahalle, Ankara, Turkey.

INTRODUCTION

Echocardiography allows investigation of the morphology and function of cardiac structures and measurement of cardiac dimensions. The knowledge of normal equine echocardiographic anatomy represents the basis for identification and interpretation of abnormal findings. Measurement of chamber dimensions is considered one of the most important tools for assessing heart disease severity and prognosis as well as for evaluating cardiac responses to training and detraining [4,11]. Accuracy and repeatability of measurements rely on the strict application of the imaging guidelines [3,9].

In this regard, echocardiographic findings should be compared with normal reference ranges. Normal reference ranges for several echocardiographic measurements have been reported for foals [5,14] ponies and adult horses [20,21] using image planes based on external anatomical landmarks. However, individual thoracic conformation could cause some leeway in the position of the plane of the beam. Intracardiac landmarks to guide transducer location, angulation and rotation, in order to obtain standardised image planes, have been described by Reef [13] and Long *et al.* [8] allowing direct comparison between different workers. By using these guidelines, normal reference ranges for cardiac dimensions of National Hunt horses,8 Thoroughbreds,17 Standardbreds, [1,4,7] small ponies, large ponies and Warmbloods19 have been reported.

The purpose of this study was to evaluate the changes of cardiac dimensions and pathological finding in intensive exercise of Thoroughbred horses on their race performance by using the 2-D Doppler and M-Mode echocardiography according to their age, body weight and sex.

MATERIALS AND METHODS

Animal selection

Thoroughbred horses (40 females and 40 males) in the facilities, Ankara and Istanbul of Racetract, of Jockey Club of Turkey were assigned as 4 study groups according to their ages and body weight separately. Group IV[1] (retired horses which is used to train for a career of jockey) and I[1,2] non-race horses were >7 year-old and >490 kg, >1 to ≤2 and ≤ 390 kg, Group II[1,2] and III[1,2] race horses were >2 to ≤3 and >390 kg to ≤ 440 kg, >3 to ≤6 year-old and >440 kg to ≤490 kg, respectively. Intensive exercise was applied to horses except group IV.

Echocardiographic Examinations

Dimensions of heart in horses were assessed before and after intensive exercise by echocardiography that were performed using an ultrasound machine (MyLab Vet30)[3] with a 2.5 MHz transducer with a maximum imaging depth of 27 cm. The focus of the transducer was fixed at 5 cm and the maximum sector angle was 110^0. Echocardiographic recordings were performed using intracardiac landmarks to orient the transducer position in order to obtain standardised images according to the previously published methods [20,21]. Two-dimensional (2-D) images from both the right and left hemithorax were used to guide the placement of the cursor and obtain accurate M-mode recordings. The inner-edge method was used for measurement of left ventricule (LV) diameter in systole and diastole (LVDd and LVDs), LV posterior wall thickness (LVPWs and LVPWd), interventricular septal thickness (IVSd and IVSs), ejection fraction (EF), fractional shortening (FS), LV mass (LVM), the ratio of the Aorta diameter to the left atrium diameter at the end diastole (LA/AoD) and the diastolic transmitral blood flow (E-wave, A-wave and E/A ratio) and calculate the Left Ventricle End Diastolic and Sistolic Volume (LVEDV and LVESV) for finding the Stroke Volume (SV) and according to the Heart Rate (HR) for Cardiac Output (CO).

Statistical Analysis

Data were statistically analysed by using parametric tests and presented in Table-1. All horses were fully trained and in competition. The horses were trained at the track, since 18 months of age; training usually consisted of a regimen of two days of slow work and one day of fast work, twice in each six-day period. The racing interval was approximately every two weeks for group II and III. Echocardiographic data can be affected by many physiological factors, such as body size [2,6,14,15,18], shape [2], physical growth [14,18], age [2], training [17], heart rate, HR [1,14] and breed [12]. Lombard *et al.* [18], studied twelve newborn pony foals until 90 days of age and found that left ventricular internal dimensions (LVID) in systole (s) and diastole (d), right ventricular internal dimensions in diastole (RVIDd), aortic diameter (AOD) and left atrial internal dimensions in systole (LADs) increased with age. Stewart *et al.* [14], studied 16 foals, 6 ponies and 10 Thoroughbreds, from birth to 90 days of age. Increased LVIDd, RVIDd, AOD, LAD, left ventricular free wall thickness (LVFWT) and interventricular septum thickness (IVST) were observed with age.

After the echocardiographic examination, the assessment of left ventricular size and function in horses have been identified by using M-Mode Echocardiography.

RESULTS

The animals presented different HR values, because of age and physical growth and level of stress during the procedures. Furthermore, animals might experience stress during echocardiographic examinations with important fluctuations in HR, depending on the character of the animal. It is well established that HR significantly influences some echocardiographic measurements. Differences in the Echocardiographic measurements in Thoroughbred of different age: Table 1 show the Echocardiographic measurements that were significantly different between age groups, in fillies and colts respectively and echocardiographic parameters presented no differences between genders and closer body weight.

Generally, the heart size increased from 2-year-old horses, through sprint and longer distance flat horses, with "bumpers" falling between the flat groups and the hurdle and steeplechase animals, with the latter being the largest in all parameters except IVSs. However, the size of the horses, as assessed by their weight, also increased from 2-yr-old horses through to sprinters and longer distance flat animals; mean weight was intermediate in Thorougbred. The mean weight differences were significantly lower in non-race group I than group IV. Differences in cardiac parameters were thus larger when unadjusted than when weight corrected. Specifically, the differences in weight-corrected measures were statistically significant between steeplechasers and all other race types for LVIDs and LV mass.

The greatest BW increase was found between group I and IV. HR was significantly lower in the group IV than the other age groups and similarly, groups III and IV presented lower mean HRs than group I. In main lines, a progressive increase in LVDd, LVDs, Aortic Measurements, LV systolic and diastolic volume and LV mass with age was found according to the Echocardiographic measurements. On the other hand, E/A index, interventricular septal thickness (IVSd and IVSs), FS%, EF%, aortic diameter were not significantly different between age groups. Significant differences of LVDd, LVDs and SV were only determined in group I compared to group IV non-race horses. Significant differences in values of CO was determined in group III compared to group II race horses, which shows the eccentric left ventricle hypertrophy developed in Thoroughbred horses during years of racing, especially more than 4 years old of intensive exercise.

The difference between LV volume and mass into age groups show the Stroke Volume and Cardiac Output is increased, especially more than 4 years of intensive exercise and has been demonstrated that an eccentric cardiac hypertrophy occurs in response to race training attributable to an increased diastolic stress and thus, higher heart chambers are expected in the trained Thoroughbred horses, which is tempting to speculate if these data are the result of the genetic selection of Thoroughbred horses for speed racing. Present study indicated that linear relationships between echocardiographic variables and age and BW were found, with the linear relationships between echocardiographic variables and age being stronger than those with body weight, and also eccentric left ventricle hypertrophy developed in Thoroughbred horses during years of racing, especially more than 4 years of intensive exercise. Win to run ratio start at the beging of 4 years old Thoroughbred horses.

DISCUSSION

Athletic superiority could be present in horses with a specific cardiac phenotype that differs between race types. As horse trainers tend to select horses for each race discipline based on their pedigree and previous race performances, it is possible that, in so doing, they are inadvertently selecting horses with a particular cardiac phenotype. Despite the horses being derived from a relatively homogeneous genetic pool, there may still be an influence of genetics in determining the cardiac phenotype of each group, Nevertheless, our results do suggest that, within a group of running athletes competing over a relatively limited distance range of 1,000–2,400 m in races lasting between 1 and 4 min, the morphology of the equine heart differs in a way that is appropriate for the likely endurance component of the horse's principle race type.

Relationships between echocardiographic measurements and body weight (BW) seem to be stronger

Table 1. Assessment of the changes of cardiac dimensions and pathological finding in intensive exercise of Thoroughbred horses on their race performance by using the 2-D Doppler and M-Mode echocardiography according to their age, body weight and sex related to 4 groups of horses.

	I (>1 to ≤2)		II (>2 to ≤3)		III (>3 to ≤6)		IV (>6 to ≤7)		*P* value
Variable	N	Mean ± S.E.M	N	Mean ± S.E.M	N	Mean ± S.E.M	N	Mean ± S.E.M	
BW (kg)	20	414.8 ± 9.88^{a}	20	452.2 ± 23.77^{ab}	20	464 ± 9.27^{ab}	20	484.2 ± 2.22^{b}	< 0.05
RVDd (cm)	20	2.76 ± 0.06^{a}	20	2.73 ± 0.08 ^{a}	20	2.84 ± 0.05^{a}	20	2.72 ± 0.06 ^{a}	0.577
IVSd (cm)	20	2.83 ± 0.13^{a}	20	3.21 ± 0.18^{a}	20	3.30 ± 0.12^{a}	20	3.28 ± 0.22^{a}	0.199
LVDd (cm)	20	9.85 ± 0.21^{a}	20	10.69 ± 0.32^{ab}	20	11.5 ± 0.26^{b}	20	12.62 ± 0.15^{c}	< 0.001
PWd (cm)	20	2.70± 0.23^{a}	20	2.81 ± 0.16 ^{a}	20	3.06 ± 0.25^{a}	20	2.79 ± 0.16^{a}	0.639
IVSs (cm)	20	4.42 ± 0.10^{a}	20	4.59 ±0.11^{a}	20	5.06 ± 0.22^{a}	20	4.66 ±0.17^{a}	0.070
LVDs (cm)	20	5.96 ± 0.27^{a}	20	5.80 ± 0.32^{a}	20	6.74 ± 0.32^{ab}	20	7.51 ± 0.32^{b}	< 0.01
PWs (cm)	20	4.14 ± 0.27^{a}	20	3.90 ± 1.58^{a}	20	4.95 ± 0.52^{a}	20	4.38 ± 0.44^{a}	0.493
EF %	20	67.00 ± 3.59^{a}	20	74.00 ± 3.65^{a}	20	69.40 ± 2.42^{a}	20	68.20 ± 2.50^{a}	0.427
FS %	20	39.20 ± 2.89^{a}	20	45.60 ± 3.08^{a}	20	41.60 ± 2.01^{a}	20	40.60 ± 1.99^{a}	0.352
LVM (kg)	20	2.77 ± 0.05^{a}	20	3.58 ± 0.27^{ab}	20	4.35 ± 0.30^{bc}	20	4.69 ± 0.22^{c}	< 0.001
AoD (cm)	20	5.68 ± 0.34^{a}	20	5.81. 0.15^{a}	20	6.15 ± 0.14^{a}	20	6.59 ± 0.34^{a}	0.102
LA (cm)	20	3.67 ± 0.16^{a}	20	4.34 ± 0.47^{a}	20	4.15 ± 0.22^{a}	20	4.98 ± 0.36^{a}	0.076
LA/AoD	20	0.64 ± 0.04^{a}	20	0.66 ± 0.03^{a}	20	0.68 ± 0.02^{a}	20	0.75 ± 0.03^{a}	0.073
E/A INDEX	20	1.26 ± 0.03^{a}	20	1.31 ± 0.04^{a}	20	1.28 ± 0.02^{a}	20	1.31 ± 0.04^{a}	0.628
LVEDV (mL)	20	547.52 ± 24.94^{a}	20	656.38 ± 43.15^{ab}	20	767.17 ± 36.82^{b}	20	937.06 ± 24.60^{c}	< 0.001
LVESV (mL)	20	179.29 ± 18.96^{a}	20	169.16 ± 21.28^{a}	20	237.01 ± 25.91^{ab}	20	302.27 ± 29.27^{b}	< 0.01
SV (mL)	20	368.23 ± 30.12^{a}	20	487.21 ± 43.33^{ab}	20	530.15 ± 25.28^{bc}	20	634.78 ± 17.60^{c}	< 0.001
HR (beat/min)	20	62.40 ± 1.33^{a}	20	57.60 ± 1.94^{ab}	20	52.60 ± 0.68^{b}	20	42.20 ± 0.58^{c}	< 0.001
CO (lt/kg/min)	20	22.872 ± 1.622^{a}	20	27.922 ± 2.287^{a}	20	27.828 ± 1.038^{a}	20	26.778 ± 0.750^{a}	0.108

than those with age [16]. In horses, the effects of training and growth [10,14,15] on echocardiographic measurements have been documented, and the influence of breed has been suggested by several authors [2,18]. In this study all of the horse have been implended intesive exercise because of it, echocardiographic parameters and body size in this species is controversial. So that the age can be more important than the body weight for Thorougbred race horses. These results could be due to the low range of body size of the horses included in this study, as other studies, involving horses with a wider range of BW, demonstrated a significant linear correlation between echocardiographic parameters and BW, indicating the need for a correction for body size in this species [2,15,21]. Previously demonstrated in several species, there is a positive and strong correlation between cardiac dimensional measurements and body size in the equine species. On the contrary, no correlation was found between LA/Ao, Pu/Ao, or FS and body size, which is in agreement with most of the previous studies in veterinary and human medicine [11,13,19].

When comparing the mean values of this study with the mean values of Arabian racehorses, a tendency for the endurance horses to present a wider left ventricle than the racehorses was noted (an eccentric left ventricle hypertrophy), a fact observed by the greater values of LVID and of LVFW thickness, either in diastole or in systole, when compared with the racehorses studied by Bilal and Meral [17]. Even when considering only the horses with a body weight of less than 378 kg, this was still seen. This trait could be a physiologic response to the type of exercise animals are submitted to [10,17], but to confirm this hypothesis, more studies are required using animals of similar biotype for different types of work.

In fact, it has been demonstrated that an eccentric cardiac hypertrophy occurs in response to race training attributable to an increased diastolic stress and thus, higher heart chambers are expected in the trained Thoroughbreds and Standardbreds horses. Patteson *et al*. demonstrated that bradycardia is associated with increased and decreased LVFWTs and IVSTs. However, our data of LVIDs were only similar to those presented by Patteson et [11] in Thoroughbred.

Despite not to calculate the EPSS in this study, which is considered an useful, practical and easily reproducible clinical index of LV blood inflow and therefore, of the LV function.

The higher values for transmitral flow (E/A index) in the older Spanish colts disagree with the results presented for Hungarian dogs of different breeds [18]. These last authors did not find any significant change in E/A index in dogs aged between 1 and 15 years.

The lack of significant differences between age groups in several LV performance indices, such as FS% and EF% might indicate that the values reported here can be extrapolated to Thorougbred horses of different ages and BW. However, this idea remains to be proven in a greater sample size of Thorougbred horses. FS% is regarded as a measurement of LV systolic function and an indicator of ventricular compliance and contractility, and FWT% and FST% are related to the degree of contractility. The lack of significant differences in these parameters in association with different body sizes and breeds has been already documented for dogs [6], and horses [1]. However, other authors found that young animals have a better myocardial contractility, because of the lower peripheral vascular resistance and/or of the higher HR. Therefore, higher values for FS%, FWT% and FST% were found in puppies [9]. In addition, demonstrated that FS% is greatly influenced by BW, with large dogs having lower values than small dogs [2,6]. As expected, SV and CO values were statistically higher in the older groups. Although CO can be used clinically as a measurement of the global heart function, it is a very insensitive indicator of cardiac performance, because many compensatory mechanisms can interact to maintain a normal CO in pathological states [15].

In horses, higher LVFWTs, LVFWTd, IVSTs and LVM in males Thoroughbred yearlings, but BW was also significantly higher in males than in females, which observed that age- and weight adjusted means for cardiac dimensions were lower in males Thoroughbreds than in females aged between 12 and 27 months [16]. In young Standardbred racehorses reported larger LVID in males. In our research, in main lines, the fillies had higher LVIDd, but lower LVIDs, LVFWTs, EPSS and LVM [4]. Additionally, the groups I and II of the fillies had lower AO measurements, E/A ratio, EPSS, LVEDV, SV and CO values, which were not statistically meaningful.

These results have demonstrated strong associations between objective measures of performance and LV dimensions in a large population of conditioned equine athletes. We have also shown that absolute and relative internal cardiac dimensions of equine athletes are affected by race discipline. As LV chamber width increases in response to dynamic exercise and endurance training in both humans and horses [2], these data suggest that conditioned racehorses develop a cardiac morphology that is appropriate to the endurance component of their event. Previous data have also shown that racehorses adapt to commercial training with increases in both wall thickness and chamber width [1], yet we were unable to detect differences in weight-corrected wall thickness in any of the groups in the present study, because of the similar body weight.

In conclusion, the animals presented different HR values, because of age and physical growth and level of stress (race or non-race) during the procedures. Furthermore, animals might experience stress during echocardiographic examinations with important fluctuations in HR, depending on the character of the animal. It is well established that HR significantly influences some echocardiographic measurements.

The results also demonstrated an association between athletic ability and measurements of LV size and function, measured by echocardiography in commercial Thoroughbred racehorses in Turkey. These relationships differed substantially between the different groups of Thoroughbreds studied, a finding that probably also reflects the altered importance of aerobic capacity in longer distance events. LV mass was also previously shown to have the strongest correlation to maximum VO_2 in horses exercising on a high-speed treadmill [4,12].

In summary, data obtained from the present study have allowed differences in cardiac morphology to be revealed in a group of conditioned running athletes, despite relatively subtle differences in the expected endurance demands of the exercise event. It seems likely that this has been made possible because of the homogenous character of the group of athletes being studied.

MANUFACTURERS
[1]Jockey Club of Turkey. Racetrack of Istanbul, Turkey.
[2]Jockey club of Turkey. Racetrack of Ankara, Turkey.
[3]Esoate Veterinary Ultrasound. Genoa, Italy.

Ethical approval. Examination procedure of horses were approved by Ethics Committee of Experimental Medicine Research and Application Ankara University (AU).

Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of paper.

REFERENCES

1 **Bakos Z., Voros K., Jarvinen T. & Reiczigel J. 2002.** Two-dimensional and M-mode echocardiographic measurements of cardiac dimensions in healthy Standardbred trotters. *Acta Veterinary Hungarica.* 50: 273-282.

2 **Brown D.J., Rush J.E., MacGregor J., Ross J.N., Brewer B. & Raud W.M. 2003.** M-mode echocardiographic ratio indices in normal dogs, cats, and horses: a novel quantitative method. *Journal of Veterinary Internal Medicine* 37: 653-662.

3 **Buhl R., Ersbøll A.K., Eriksen L. & Koch J. 2004.** Sources andmagnitude of variation of echocardiographicmeasurements in normal Standardbred horses. *Veterinary Radiol Ultrasound.* 45: 505-512.

4 **Buhl R., Ersbøll A.K., Eriksen L. & Koch J. 2005.** Changes over time in echocardiographic measurements in young Standardbred racehorses undergoing training and racing and association with racing performance. *Journal of the American Veterinary Medical Association*. 226: 1881-1887.

5 **Collins N.M., Palmer L. & Marr C.M. 2010.** Two-dimensional and M-mode echocardiographic findings in healthy Thoroughbred foals. *Australian Veterinary Journal*. 88: 428-433.

6 **Gonçalves A.C., Orton E.C., Boon J.A. & Salman M.D. 2002.** Linear, logarithmic and polynomial models of M-mode echocardiographic measurements in dogs. *American Journal of Veterinary Research.* 63: 994-999.

7 **Kriz N.G. & Rose R.J. 2002.** Repeatability of standard transthoracic echocardiographic measurements in horses. *Australian Veterinary Journal*. 80: 362-370.

8 **Long K.J., Bonagura J.D. & Darke P.G. 1992.** Standardised imaging technique for guided M-mode and Doppler echocardiography in the horse. *Equine Veterinary Journal*. 24: 226-235.

9 **Menzies-Gow N.J. 2008.** Effects of sedation with acepromazine on echocardiographic measurements in eight healthy thoroughbred horses. *Veterinary Record*. 163(1): 21-25.

10 **Nikolaus G.K., Reuben J.R. & David R.H. 2004.** *Manual of Equine Practice.* Philadelphia: Saunders Elsevier, pp. 232-237.

11 **Patteson M.W., Gibbs C., Wotton P.R. & Cripps P.J. 1995.** Echocardiographic measurements of cardiac dimensions and indices of cardiac function in normal adult thoroughbred horses. *Equine Veterinary Journal.* 19: 18-27.

12 **Poole D.C. 2004.** Current concepts of oxygen transport during exercise. *Equine and Comparative Exercise Physiology*. 1: 5-22.

13 **Reef V.B. 1990.** Echocardiographic examination in the horse: the basics. *Compendium on Continuing Education for the Practising Veterinarian.* 12: 1312-1320.

14 **Reef V.B., Lalezari K., De Boo J., Belt A.J., Spencer P. & Dik K.J. 1989.** Pulsed-wave doppler evaluation of intracardiac blood flow in 30 clinically normal Standardbred horses. *American Journal of Veterinary Research*. 50 (1): 75-83.

15 **Rovira S., Muñoz A. & Rodilla V. 2009.** Allometric scaling of echocardiographic measurements in healthy Spanish foals with different body weight. *Research in Veterinary Science.* 86: 325-331.

16 **Seder J.A., Vickery C.E. & Miller P.M. 2003.** The relationship of selected two-dimensional echocardiographic measurements to the racing performance of 5431 yearlings and 2003 two-year-old thoroughbred racehorses. *Journal of Equine Veterinary Science*. 23: 149-167.

17 **Vollmar A.C. 1999.** Echocardiographic measurements in the Irish wolfhound: reference reference values for the breed. *Journal of the American Animal Hospital Association.* 35: 271-277.

18 **Vörös K., Hetyey C., Reiczigel J. & Czirok G.N. 2009.** M-mode and twodimensional echocardiographic reference values for three Hungarian dog breeds: Hungarian Vizsla, Mudi and Hungarian Greyhound. *Acta Veterinaria Hungarica*. 57: 217-227.

19 **Young L.E., Marlin D.J., Deaton C., Brown-Feltner H., Roberts C.A. & Wood J.L.N. 2002.** Heart size estimated by echocardiography corelates with maximal oxygen uptake. *Equine Veterinary Journal*. 34: 467-472.

20 **Young L.E., Rogers K. & Wood J.L. 2005.** Left ventricular size and systolic function in Thorougbred racehorses and their relationships to race performance. *Journal of Applied Physiology*. 99 (4): 1278-1285.

21 **Zucca E., Ferrucci F., Croci C., Di Fabio V., Zaninelli M. & Ferro E. 2008.** Echocardiographic measurements of cardiac dimensions in normal Standardbred racehorses. *Journal of Veterinary Cardiology*. 10: 48-51.

http://dx.doi.org/10.22456/1679-9216.84209