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RESEARCH ARTICLE

M-Mod Echocardiographic Investigation of Cardiac Dimensions and Function Indices in Growing Thoroughbred Foals Reared in Turkey

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Summary

The aim of this study was to obtain reference values of cardiac dimensions and indices of function in Thoroughbred foals. In total 76 Thoroughbred foals (48 female, 28 male) were used in this study. The M-mode echocardiographic data of foals were obtained from birth until 24 months of age at 4 month intervals Most of the investigated parameters increased constantly with age except some fluctuations. Right ventricular internal diameter in diastole (RVIDd) was significantly higher in females than in males at the 4th month ($P<0.05$). On the other hand RVIDd tended to be higher in males than in females in the previous and next age groups ($P<0.10$). Left ventricular mass (LVM) was higher in males than in females at 8th month ($P<0.05$). In addition, left ventricular free wall thickness in systole (LVFWTs) values obtained at the 12th month in females and 20th month in males tended to be higher ($P<0.10$). Heart rate (HR) constantly decreased with age and tended to be higher in females than in males at the 8th month ($P<0.10$). As a conclusion the normal limits of echocardiographic parameters were found to be different in growing foals compared to that of adults and some gender based variations were determined. Therefore age and gender differences should be taken into account during interpretation of echocardiographic data.

Keywords: *Horse, Echocardiography, Heart dimensions, Cardiac function indices*

Türkiye'de Yetiştirilen Safkan İngiliz Taylarının Büyüme Döneminde Kalp Boyutlarının ve Fonksiyon İndekslerinin M-Mod Ekokardiyografi İle İncelenmesi

Özet

Bu çalışmanın amacı safkan İngiliz yarış atlarında kalp boyutlarına ve fonksiyon indekslerine ilişkin referans değerlerin elde edilmesidir. Bu çalışmada Toplam 76 adet (48 dişi 28 erkek) safkan İngiliz tayı kullanıldı. Doğum sonrası 24. aya kadar 4 ayda bir M-mod ekokardiyografik veriler elde edildi. Elde edilen sonuçlar bazı dalgalanmalar olmakla birlikte ölçülen çoğu parametrede yaşa bağlı artış olduğunu gösterdi. Sağ ventrikülün diastoldeki iç çapı (RVIDd)'nın 4. ayda dişilerde erkeklere göre daha yüksek olduğu belirlendi ($P<0.05$). Öte yandan bir önceki ve bir sonraki yaş gruplarına ait RVIDd değerlerinin erkeklerde dişilere göre daha yüksek olduğu yönünde bir eğilim görüldü ($P<0.10$). Sol ventrikül kitlesi (LVM) 8. ayda erkeklerde dişilerden daha yüksekti. ($P<0.05$). Ayrıca LVFWTs'nin 12. ayda dişilerde 20. ayda erkeklerde daha yüksek olma eğiliminde olduğu görüldü ($P<0.10$). HR yaşa bağlı olarak düzenli olarak azaldığı ve 8. ayda dişilerde erkeklere göre daha yüksek olma eğiliminde olduğu görüldü ($P<0.10$). Sonuç olarak ekokardiyografik parametrelerin normal limitlerinin erişkin atlardan farklı olduğu ve cinsiyete bağlı bazı faklılıklar olabileceği belirlendi. Bu nedenle ekokardiyografik veriler yorumlanırken yaş ve cinsiyet farklılıkları göz önünde bulundurulmalıdır.

Anahtar sözcükler: *At, Ekokardiyografi, Kalp boyutları, Kardiyak fonksiyon indeksleri*

INTRODUCTION

Echocardiography has been widely used for the diagnosis and prognosis of congenital and acquired heart diseases in equine medicine [1]. It is also preferred as a non-invasive method for evaluation of fitness [2], determination of poor performance [3,4], efficiency of training programs [5] or the effect of deconditioning on cardiac dimensions and

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indices of cardiac function in equine athletes [6]. Because it is considered that there is a correlation between morphological features of the heart and race success [7] the echocardiographic examination has been used in pre-purchase examinations and insurance procedures [8]. Echocardiography was introduced into equine cardiology, measurements of cardiac dimensions were started in 1977 [9], but standardization of imaging techniques and obtaining reference values has been continued until recent years [10,11]. Because echocardiographic values are influenced by body weight, conformation, gender, breed, age or the training procedures [12], there is a need for new studies in equine sport medicine in order to obtain precise reference values. Despite the fact that there are many published data about morphological or functional features of heart in the adult horse [12,13], there are only a few studies on the growing foals. In two of these studies [14,15], foals were observed only until 3 months of age, in the other study [16] observations were continued for one year. It was observed that in these studies cardiac sizes and cardiac function indices change with age in growing foals. In addition, echocardiographic measurement has shown that age is also an important factor in the young Standardbred horse [17]. To our knowledge, there is no research in which entire growing period of foals was observed.

Echocardiographic examinations not only provide information about the normality of the development of the heart in growing foals, but also could reveal future cardiovascular problems in unraced foals. These could constitute a selection criterion which also could prevent horse owners from wrong investment. Moreover it has been suggested that a relationship may exist between cardiac dimensions or function indices in growing period and athletic potential in the pre-race training period in Thoroughbred foals [18]. Hence there is a need for reference values of cardiac size and function in the developmental stage of foals.

When examining cardiac problems in the horse it is necessary to know the reference values of that particular breed [10]. Different thoracic conformation of different breeds restricts the accuracy when doing comparisons. In addition the interpretations of echocardiographic data are more complicated in foals of different age. Moreover different nutrition and rearing procedures in different farms contribute to this variation and shows that evaluating these values could become complex [1]. Therefore there is a need for echocardiography values obtained from Thoroughbred horses raised in Turkey.

The aim of this study was to obtain reference values of cardiac dimensions and indices of function starting from birth till pre-race period of twenty four months age, in Thoroughbred horses in Turkey.

MATERIAL and METHODS

Foals, Care and Raising Conditions

A total of 76 healthy Thoroughbred foals (28 males and 48 females) were subjected to echocardiographic examination in this study. The study was conducted at the facilities belonging to Jockey Club of Turkey located in Izmit, Istanbul and Karacabey. During the entire study standard procedures were undertaken in care, nutrition, housing, education and training. No interventions in these procedures were carried out in interest of the study.

Echocardiographic Measurements

A clinical examination was carried out prior to echocardiographic measurements, paying special attention to the cardiorespiratory system. Echocardiographic examinations were performed without changing their usual daily program. Age group was taken into consideration when echocardiographic measurements were performed. Foals until 4 months old, were examined next to their mothers in their own boxes, with two grooms holding the foal at a standing position, without causing any stress. Weaned foals were examined with the help of two grooms in the same way before. No sedation was used in any examination.

For horses younger than 8 months old a frequency of 3.5 Mhz and for older horses a frequency of 2.5 Mhz were used during the examinations. In the echocardiographic examinations the right forelimb was positioned slightly forward of the left forelimb to facilitate scanning in the right cardiac window [10]. The skin of the right cardiac window was cleaned before examination by ultrasonic coupling gel. The echocardiographic measurement was carried out by means of an Esaote Caris Plus® ultrasound system with a phased-array multifrequency transducer (Biomedica Geneva Italy). The transducer was placed on the right hemithorax where an imaginary horizontal line drawn from the level of the olecranon intersects the 4th intercostal space. One entire heart cycle in the longitudinal four-chamber view was recorded in B-mode. To achieve this, the transducer was placed in the 4th intercostal space and rotated slightly in dorsal plane to one o'clock, with an angle targeting the left 5th intercostal space. Subsequently the transducer was rotated 90 degrees clockwise and a short axis view was obtained [19], hereafter at least three cycles were recorded in the simultaneous M-Mode screen view. The recordings were later analyzed to obtain echocardiographic parameters with the particular software of the ultrasound machine.

Investigated Echocardiographic Parameters

In order to determine cardiac dimensions and function indices, echocardiographic measurements were performed at 4 month intervals until 24th month after birth. The following parameters were obtained to assess morphological

and functional changes of the heart: Left ventricular internal diameter in systole and diastole (LVIDs and LVIDd), right ventricular internal diameter in diastole (RVIDd), inter-ventricular septum thickness in systole and diastole (IVSs and IVSd), left ventricular free wall thickness in systole and diastole (LVFWTs and LVFWTd), left ventricular mass (LVM), mean wall thickness (MWT), relative wall thickness (RWT) heart rate (HR), fractional shortening (FS), ejection fraction (EF) and interventricular septum thickening percentage (IVST%).

Statistical Analysis

In order to obtain reference values, minimum, maximum, means and standard deviation of means were calculated as descriptive statistic. The differences between males and females were determined by independent sample T test. All statements of significance were based on $P<0.05$ and tendencies were indicated if P value is between 0.05 or 0.10. All statistical analyses were performed using SPSS 13.0 software (SPSS, Tulsa, OK, U.S.A.).

RESULTS

The results of the equine heart chamber dimensions and interventricular thickness of wall are presented *Table 1*. The obtained results from echocardiographic measurements indicated that LVIDs, LVIDd, RVIDd, IVSs and IVSd increased constantly in relation with age except some fluctuations. In addition there were no significant differences between male and female except RVIDd on above mentioned parameters. It was observed that RVIDd was significantly higher in female foals than in males at the 4th month ($P<0.05$). On the other hand RVIDd tended to be higher in males than females in the previous and next age groups ($P<0.10$). The results show that IVSs and IVSd increased regularly in relation with age and IVSs and IVSd reached to the maximum level at the 24 and 16 month respectively.

The *Table 2* shows minimum-maximum values, arithmetic means and standard deviations of LVM, LVFWTs, LVFWTd, MWT and RWT parameters in growing Thoroughbred foals until 24 month age. The results indicated that above mentioned parameters increased in relation with age except RWT. It was observed that LVM was higher in male foals than in females at 8th month ($P<0.05$). Furthermore, LVM tended to be higher in males than in females in the 24 month old ($P<0.10$). Left ventricular free wall thickness in systole and diastole generally increased in relation with age. Furthermore, the LVFWTs values obtained at the 12th month in females and 20th month in males tended to be higher ($P<0.10$). On the other hand there was no difference between male and female on the LVFWTd, MWT and RWT parameters.

The HR, indices of left ventricular function and IVST measurements are presented in *Table 3*. The results showed that HR was approximately 90 bpm in the 1 month old foals. Afterwards it was constantly decreased in relation with age and reached to 47.4±10.3 and 45.6±8.5 bpm in males and females respectively at the 24th month. Furthermore there were no differences between male and female except 8th month. In addition the high standard deviation was also prominent in HR. There were no significant differences between male and females on EF, FS and IVST parameters at the investigated age groups. It

Table 1. *M-mod echocardiographic measurements of LVIDs, LVIDd, RVIDd, IVSs and IVSd in growing Thoroughbred foals*
Tablo1. *Safkan İngiliz taylarında LVIDs, LVIDd, RVIDd, IVSs ve IVSd'ye ilişkin M-mod ekokardiyografik ölçümler*

A	Sex	n	LVIDs (cm)			LVIDd (cm)			RVIDd (cm)			IVSs (cm)			IVSd (cm)		
			Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
1	M	28	3.04	5.70	4.25±0.58	5.47	7.75	6.40±0.57	0.91	3.19	1.61±0.48	2.20	3.50	2.82±0.30	1.60	2.51	2.01±0.23
	F	48	3.42	5.93	4.73±0.65	4.79	7.60	6.38±0.58	0.68	2.81	1.41±0.40	1.98	3.42	2.71±0.28	1.52	2.58	1.98±0.26
4	M	18	3.72	5.78	4.79±0.62	5.78	7.98	5.78±0.63	0.99	2.43	1.69±0.41	2.28	3.72	3.05±0.34	2.13	2.96	2.32±0.21
	F	26	3.95	5.70	4.67±0.51	5.78	8.13	7.04±0.57	1.14	3.19	2.01±0.57	2.51	3.65	3.07±0.32	1.60	2.66	2.22±0.25
8	M	14	4.18	5.78	4.94±0.38	6.99	8.21	7.61±0.32	0.99	2.74	2.16±0.51	3.04	3.72	3.50±0.24	2.05	2.96	2.46±0.03
	F	14	4.33	5.24	4.84±0.24	7.22	8.06	7.53±0.21	1.14	2.43	1.81±0.46	2.58	3.72	3.37±0.31	2.05	2.66	2.28±0.15
12	M	18	4.15	6.52	5.42±0.79	7.90	9.78	9.01±0.45	1.78	3.85	2.82±0.59	3.36	4.49	3.94±0.41	2.37	3.46	2.78±0.27
	F	13	4.05	6.22	5.05±0.82	7.71	9.88	8.68±0.67	1.78	3.75	2.70±0.68	3.36	4,74	4,07±0.40	1.98	3.16	2.66±0.40
16	M	14	4.64	6.82	5.70±0.60	8.99	10.47	9.55±0.40	1.28	4.05	2.39±0.72	3.56	4.74	4.30±0.37	2.47	3.36	2.95±0.23
	F	12	4.29	7.01	5.62±0.90	7.93	11.76	9.34±1.06	1.58	3.28	2.36±0.49	3.75	4.94	4.25±0.37	2.57	3.36	2.92±0.23
20	M	13	4.05	7.45	5.83±1.12	8.00	10.87	10.11±0.85	1.88	4.05	2.77±0.48	3.56	5,32	4,53±0.40	2.47	3.36	2.89±0.29
	F	13	4.35	6.82	5.59±0.76	8.72	11.16	9.91±0.74	1.68	4.05	2.56±0.63	3.56	5.43	4.38±0.57	2.37	3.51	2.91±0.33
24	M	14	4.74	7.45	5.91±0.82	9.26	11.70	10.16±0.70	1.98	3.19	2.50±0.42	4.36	5.32	4.70±0.24	2.45	3.36	2.82±0.25
	F	17	4.58	6.32	5.25±0.56	9.15	10.87	9.80±0.52	1.81	3.19	2.55±0.50	3.83	5.32	4.74±0.36	2.34	3.30	2.74±0.29

LVIDs: *Left ventricular internal dimensions in systole,* ***LVIDd:*** *Left ventricular internal dimensions in diastole,* ***RVIDd:*** *Right ventricular internal dimensions in systole,* ***IVSs:*** *Interventricular septum thickness in systole,* ***IVSd:*** *Interventricular septum thickness in diastole,* ***A:*** *Age (Month),* ***M:*** *Male,* ***F:*** *Female,* ***Min:*** *Minimum,* ***Max:*** *Maximum,* ***SD:*** *Standard deviation.* ****:*** *P<0.05,* ***†:*** *P<0.10*

Table 2. *M-mod echocardiographic measurements of LVM, LVFWTs, LVFWTd, MWT and RWT'in growing Thoroughbred foals*
Tablo 2. *Safkan İngiliz taylarında LVM, LVFWTs, LVFWTd, MWT ve RWT'ye ilişkin M-mod ekokardiyografik ölçümler*

A	Sex	n	LVM (g)			LVFWTs (cm)			LVFWTd (cm)			MWT (%)			RWT (%)		
			Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
1	M	28	386	933	666±160	1.75	3.27	2.26±0.38	0.84	1.75	1.29±0.22	1.33	2.13	1.64±0.21	0.38	0.71	0.518±0.09
	F	48	403	1050	669±175	1.09	2.96	2.24±0.33	0.68	2.36	1.28±0.31	1,22	2,13	1.64±0.22	0.39	0.71	0.515±0.07
4	M	18	617	1277	972±178	1.82	2.96	2.46±0.31	1.06	2.05	1.54±0.24	1.60	2.36	1.94±0.19	0.46	0.74	0.557±0.08
	F	26	484	1297	934±197	2.05	3.27	2.62±0.36	1.14	1.90	1.49±0.18	1.41	2.13	1.85±0.17	0.41	0.62	0.529±0.05
8	M	14	966	1576	1289±188	2.43	3.34	2.96±0.24	1.52	2.0	1.82±0.16	1,90	2,39	2.14±0.20	0.47	0.64	0.565±0.05
	F	14	930	1407	1170±119	2.36	3.27	2.87±0.27	1.29	2.20	1.76±0.29	1,83	2,24	2.03±0.13	0.47	0.59	0.541±0.03
12	M	18	1206	2778	1945±309	2.87	4.35	3.46±0.38	1.48	2.67	1.96±0.38	1.98	3.07	2.37±0.25	0.45	0.69	0.528±0.06
	F	13	1206	2113	1804±241	2.96	4.64	3.76±0.51	1.48	2.67	2.04±0.36	1.98	2.52	2.35±0.16	0.43	0.63	0.544±0.06
16	M	14	1762	2999	2506±393	3.16	4.84	3.81±0.54	1.78	3.06	2.32±0.41	2.13	3.02	2.64±0.26	0.45	0.64	0.552±0.05
	F	12	1924	2934	2313±309	3.26	4.94	3.84±0.60	1.78	2,83	2.26±0.35	2.18	3.02	2.59±0.21	0.37	0.71	0.563±0.09
20	M	13	1778	3399	2728±453	3.16	6.03	4.41±0.88	1.98	2.96	2.41±0.37	2.28	3.03	2.65±0.22	0.45	0.69	0.527±0.07
	F	13	1932	3554	2485±431	3.09	4.74	3.89±0.52	1.68	3.06	2.19±0.46	2.32	3.03	2.55±0.25	0.45	0.69	0.516±0.06
24	M	14	2536	3668	3051±437	3.75	6.03	4.56±79	1.98	3.62	2.80±0.53	2.52	3.25	2.83±0.22	0.46	0.66	0.558±0.06
	F	17	2272	3566	2758±400	3.72	5.75	4.69±0.68	2.23	3.62	2.82±0.43	2.45	3.35	2.75±0.23	0.46	0.70	0.568±0.06

LVM: Left ventricular mass, ***LVFWTs:*** Left ventricular free wall thickness in systole, ***LVFWTd:*** Left ventricular free wall thickness in diastole, ***MWT:*** Mean wall thickness ***RWT:*** Relative wall thickness, ***A:*** Age (Month), ***M:*** Male, ***F:*** Female, ***Min:*** Minimum, ***Max:*** Maximum, ***SD:*** Standard deviation. ****:*** *P*<0.05, ***†:*** *P*<0.10

Table 3. *M-mod echocardiographic measurements of the functional indices of the heart in growing Thoroughbred foals*
Tablo 3. *Safkan İngiliz Taylarda kalbin fonksiyon indekslerine ilişkin M-mod ekokardiyografik ölçümler*

Age	Sex	n	HR (bpm)			EF (%)			FS (%)			IVST% (cm)		
			Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
1	M	28	67	142	90.9±17.9	43	81	60.5±8.3	22	50	33.7±6.1	6	100	43.0±22.2
	F	48	61	137	90.8±17.7	42	71	58.5±8.2	21	41	31.9±5.6	3	88	38.6±20.5
4	M	18	58	142	74.5±20.2	47	71	57.8±7.0	25	41	31.6±4.7	3	63	31.8±16.7
	F	26	50	113	74.0±14.9	47	73	60.8±6.9	24	43	33.7±5.1	12	100	39.5±19.8
8	M	14	42	77	55.9±7.5	54	70	62.7±5.7	29	40	35.5±4.2	23	81	44.4±20.3
	F	14	42	89	63.2±13.0	53	71	63.6±5.5	28	41	36.0±4.1	13	81	48.1±20.1
12	M	18	45	64	52.4±7.0	54	80	67.7±8.9	29	51	39.8±7.5	20	80	42.0±20.1
	F	13	45	75	54.2±8.8	50	83	69.5±9.4	27	53	41.3±7.7	17	105	59.5±30.1
16	M	14	42	64	52.9±6.1	58	80	69.8±7.5	32	51	41.7±6.3	15	80	50.9±21.0
	F	12	42	64	53.9±6.2	57	78	67.5±7.3	32	48	39.7±5.8	15	85	46.6±20.7
20	M	13	42	69	51.1±10.5	63	83	74.0±6.4	36	55	45.5±5.9	31	88	60.7±18.4
	F	13	42	52	47.6±2.8	49	85	68.3±11.6	26	56	40.9±9.6	24	88	55.0±24.2
24	M	14	33	69	47.4±10.3	63	83	70.8±6.9	36	55	42.7±6.3	38	91	69.8±18.1
	F	17	32	69	45.6±8.5	62	83	74.8±7.1	35	55	46.2±6.5	40	114	74.7±22.8

HR: *Heart rate,* ***EF:*** *Ejection fraction,* ***FS:*** *Fractional shortening,* ***IVST%:*** *Interventricular septum thickening percentage,* ***A:*** *Age (Month),* ***M:*** *Male,* ***F:*** *Female,* ***Min:*** *minimum,* ***Max:*** *maximum,* ***SD:*** *Standard deviation,* ***†:*** *P<0.10*

was indicated that the minimum and maximum values of IVST shown huge variation in growing foals. Furthermore, the standard deviation of means was also high comparing to other parameters.

DISCUSSION

Since echocardiography is a non-invasive technique, it might be used efficiently in diagnosis of the cardiovascular system diseases and also monitoring the development of the heart [16]. The 2-year developmental period following birth is important especially in race horses. Detection of cardiovascular system problems in this period will protect the breeders from uneconomical investments. Clinical reference values are required for comparison with values. However, reference values regarding echocardiographic measurements of the above mentioned 2-year developmental period following birth is limited. In the current study morphological and functional characteristics of the heart were investigated by echocardiography in

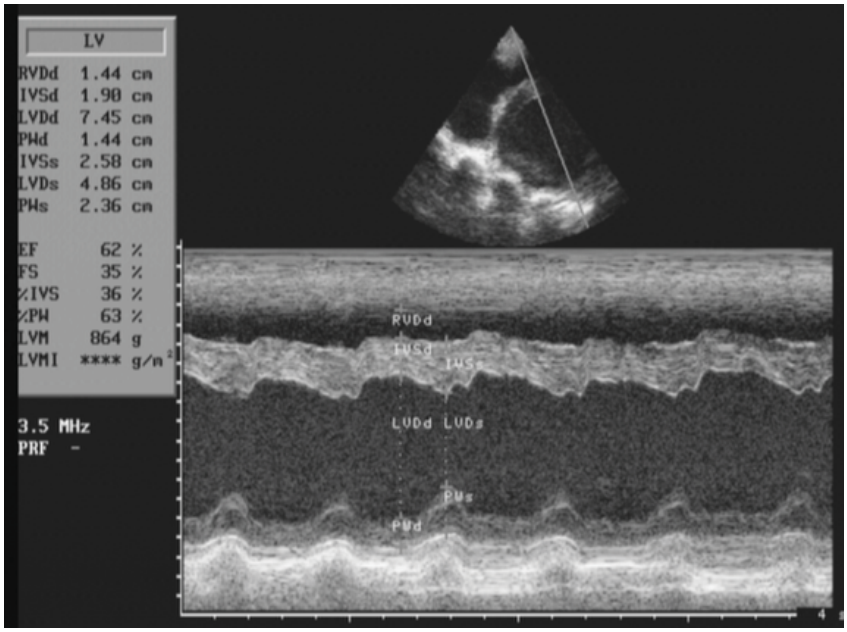

Fig 1. B-mod and M-mod echocardiogram obtained from the right parasternal cardiac window using a frequency of 3.5 Mhz in 1 month old thoroughbred foal

Şekil 1. Bir aylık safkan İngiliz tayında sağ hemitorakstaki kardiyak pencereden 3.5 Mhz frekansta alınan B-mod ve M-mod ekokardiyogram

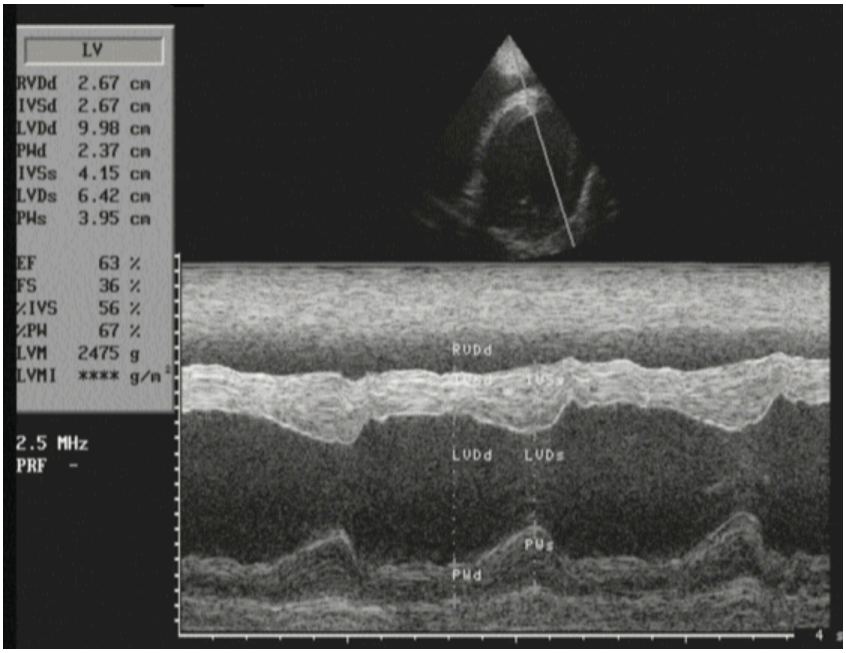

Fig 2. B-mod and M-mod echocardiogram obtained from the right parasternal cardiac window using a frequency of 2.5 Mhz in 20 months old thoroughbred foal

Şekil 2. Yirmi aylık safkan İngiliz tayında sağ hemitorakstaki kardiyak pencereden 2.5 Mhz frekansta alınan B-mod ve M-mod ekokardiyogram

Thoroughbred foals during the 2-year developmental period following birth.

Internal diameter of left ventricle during systole and diastole are widely used parameters in echocardiographic examinations. These parameters are used to determine the eccentric hypertrophies in sportsmen [20]. It has been reported that these parameters might increase in young racing horses due to training [21] or due to some pathological reasons such as aortic insufficiency [22]. Furthermore, these parameters are important for the detection of overload of the left ventricle in valvular insufficiencies, mitral and aortic regurgitations or myocardial diseases [1]. In the current study it was found that LVIDs and LVIDd increased with age, but gender was not a significant factor for these parameters. LVIDs and LVIDd determined in 24-month old foals in the current study were lower than those determined in adult horses [8]. On the other hand, our results are comparable to the results obtained from Spanish foals investigated during a 1-year period following birth [16].

Generally the left ventricle is preferred in echocardiographic examinations since measurement of RVID is known to be less repeatable than left ventricular measurement in horse [23]. Echocardiographic examination of the right ventricle is also suggested in horses because of the effects of tricuspid valve insufficiencies, which is common in horses. Since we could not find any research reporting

normal reference values of RVIDd for foals younger than 2-year old, we could not compare our results. However, RVIDd values determined in the current study were lower than those of adult horses [25]. Stewart et al.[14] reported an increase in RVIDd with age, although they did not investigate the difference between adult horses and growing foals. Therefore, being higher the values reported for adult horses than those obtained from foals in the current study was interpreted as a normal result. In the current study, RVIDd determined in 4-month foals was higher in females than in males; however it was higher in males than in females both in the previous and the next age groups. Any research reporting whether there is a difference or not between males and females could not be found. However, it has been reported that, there is not a difference between males and females for dogs [26]. Conflicting results obtained from 3 different age groups in the current study might be related with limited reproducibility of the measurements [23].

Interventricular septum thickness is one of the echocardiographic parameters used to investigate the effect of exercise in race horses. It has been reported that [27], in race horses, IVSd is higher at the end of the racing season than that of determined in the beginning of the racing season. Furthermore, IVS has been found to be higher in endurance- trained horses than strength-trained horses [28]. Although the foals investigated in the current study were in growing period, it has been reported that some pathological situations might affect interventricular septum thickness [29]. Therefore, IVSs and IVSd might be required to be checked during echocardiographic examination of the heart in growing foals. In the current study, IVSs and IVSd determined in 24-mont old foals were comparable with those reported previously [30]. IVSs and IVSd determined in other age groups could not be evaluated since any reported data including the 2-year period following birth could not be found. On the other hand, any significant difference in respect of IVSs and IVSd was not found between males and females.

Left ventricular mass is one of the parameters providing information about the whole of left ventricle since it is calculated from free wall thickness of left ventricle, interventricular septum thickness and internal diameter of left ventricle [31]. It is used for evaluation of cardiac hypertrophies in human [32] and race horses [30]. In the present study, it was found that LVM increased regularly with age. It is obvious that this is a natural outcome of normal physiologic growing [31]. LVM values determined in 24-month old foals in the current study are quite similar with the LVM values determined in 2-year old Standardbred horses [17]. In the current study, LVM values determined in Thoroughbred foals during the first 24-month period were generally higher in males than females. Moreover, the differences between males and females were statistically significant on months 8 and 24. Similarly, higher LVM values in males than in females were reported for adult Thoroughbreds [30].

Free wall thickness of left ventricle during systole or diastole is one of the echocardiographic parameters that are used to investigate the effects of training on heart in race horses. It has been reported that while LVFWTs increases, on the contrary LVFWTd decreases during deconditioning period after training in race horses [6]. However these two parameters are not only used for investigating the training related adaptations, but also detection of valve regurgitation, myocardial diseases such as patent ductus arteriosus, septal defect, anemia or aortic regurgitation and left ventricular overload [1]. Therefore these parameters can be used for both adult racing horses and also for foals and yearlings. In this study LVFWTd linearly increased with age and after 12th month, it reached to the values that measured on 3-4 years old standardbred geldings [6]. Such an increase may be explained by increased free left ventricle wall contractility to exceed age dependently increased peripheral resistance. Moreover differences between males and females may be the result of the same reason.

Mean wall thickness is arithmetic average of free wall thickness of left ventricle and interventricular septum during diastole. It represents the ventricle thickness. It is also one of the parameters used for determination of adaptation to training [10]. It has been reported that mean heart wall thickness increases with training in human [31]. MWT increase has been also reported in flat race horses under traditional training programs [5]. Furthermore it has been indicated that MWT increases with age in Standardbred race horses examined by echocardiography at 6 months intervals and it is correlated with body weight [17]. Similarly, in our study MTW increases with age.

Relative wall thickness is calculated by adding left ventricle free wall thickness to interventricular septum thickness and then dividing this to internal diameter of left ventricle during diastole [33]. This is one of the parameters used for determination of cardiac adaptation specific to sport branch in human and horses [5]. It has been reported that RWT is lower in athletes doing endurance-related sports; on the contrary it is higher in athletes doing strength-related sports [28]. In the present study, left ventricle associated other parameters increased concomitantly with the increase in age of the foal or yearling. However there was not steady increase or decrease in RWT. It was reported that RWT and body weights are not correlated in Standardbred horses [17]. This supports our findings indicated that although body weight increased in growing foals, RWT did not changed. Furthermore, MWT and RWT did not differ between males and females until 2 years old age. Similarly no effect of gender has been reported in adult horses [30].

Heart rate can be changed depending on many

physiological factors. In addition various pathological situations may affect heart rate [34]. HR may affect parameters associated with heart dimensions and functional indexes in humans and horses during echocardiographic measurements [1]. Because HR is more unstable in foals and yearlings compared to adult horses, it should be taken into account during echocardiographic measurements. In the present study heart rate was 90 in one month old foals, decreased with age and reached to 45-50 per minute in 2 years old yearlings. HR values measured until 4 month olds are compatible with the values obtained from Spanish foals [1]. Furthermore HR decrease with age has been reported in previous studies [15], although first few months after parturition have been investigated in these studies. In the present study decrease in HR continued until 2 years age. The other finding related to HR is there was a big difference between maximum and minimum values especially in first few months. In this period standard deviation of means were also high. Because foals are more sensitive to environmental stimulants during early ages, big differences between maximum and minimums were considered to be inevitable. HR of 8 months old female foals tended to be higher than that of males. There was no suitable explanation why this difference occurred only during this period. This difference may be due to the sensitivity of female foals to environmental stimulants during this period or due to the different metabolic and hormonal activities of females. Nevertheless it is not possible to explain it fully.

The ejection fraction is the percentage of the left ventricular volume that is ejected with systole; that is, the ejection fraction is the ratio of stroke volume to the end-diastolic volume [35] . It has been reported that EF and race success are associated and it can be used as an indicator of cardiac functions [30]. Furthermore studies that were associated EF with training programs have reported both decrease in EF depending on training [5], and also some of them reported no change [36] . In the present study there was not linear age dependent decrease or increase in EF, unlike other parameters. The obtained results are in accordance with the EF results that were measured by in total of 20, various bred adult horses [37]. Similar to our results, It was reported that there is no linear correlation between EF and the age in cats [38].

Fractional shortening is the percentage of change in the left ventricular cavity dimension with systole [35]. FS is commonly used clinical measurement of the global LV systolic function and an indicator of ventricular compliance and contractibility [1]. Results of the present study indicated that FS did not show significant variation except first 4 months same like EF. This could be related to the low peripheral resistance during first few months [39]. Normal reference ranges of FS reported to be between 32-45% and below this levels were associated with pathological conditions in studies carried out on adult horses. In the present study, considering minimum and maximum values especially during the first months, some horses had values below the indicated limits, yet there were not found any cardiovascular problems by clinical examinations. The lower results obtained from foals compared to that of adult horses considered to be normal in this study and explained by lower peripheral resistance in young horses than that of adults.

Interventricular septum thickening percentage is used as a functional indicator of left ventricle. It is calculated using interventricular septum thickness during systole and diastole [38] and used for determining contractile features of the heart. In the present study, there were significant differences between maximum and minimum values especially in younger horses and also SD was considerably high. It has been reported that similar fluctuation has been in growing cats and it is quite difficult to set reference values. Nevertheless IVST values of 24 month old yearlings in the present study are quite similar to values obtained from adult horses [40]. However there was also a difference between maximum and minimum values in adult horses same like youngsters and SD was also considerably high.

The results of this study give useful reference values of dimensions and indices of cardiac function in growing Thoroughbreds. Considering investigated parameters, normal limits of echocardiographic parameters were found to be different in growing foals compared to that of adults and some variations were observed between males and females time to time. Therefore it is concluded that when interpreting results of echocardiographic examination in a foal, it would be beneficial to compare these results with the results of other foals at similar ages.

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REFERENCES

1. Rovira S, Muñoz A, Rodilla V: Allometric scaling of echocardiographic measurements in healthy Spanish foals with different body weight. *Res Vet Sci,* 86, 325-331, 2009.

2. Michima LE, Latorre SM, Cesar de Andrade AF, Fernandes WR: B-mode and M-mode echocardiography of endurance horses raised in Sao Paulo State, Brazil. *J Equine Vet Sci* 24, 451-457, 2004.

3. Morris EA, Seeherman HJ: Clinical evaluation of poor performance in the racehorse: The results of 275 evaluations. *Equine Vet J,* 23, 169-174, 1991.

4. Zucca E, Ferrucci F, Stancari G, Saporiti T, Ferro E: The prevalence of cardiac murmurs among standardbred racehorses presented with poor performance. *J Vet Med Sci*,72, 781-785, 2010.

5. Young L: Cardiac responses to training in 2-year-old thoroughbreds an echocardiographic study. *Equine Vet J Suppl,* 30, 195-198, 1999.

6. Kriz NG, Hodgson DR, Rose RJ: Changes in cardiac dimensions and indices of cardiac function during deconditioning in horses. *Am J Vet Res*, 61,1553-1560, 2000.

7. Lightowler C, Piccione G, Giudice E, Del Olmo GR, Cattaneo ML: Echocardiography and electrocardiography as means to evaluate potential performance in horses. *J Vet Sci,* 5, 259-262, 2004.

8. Reef VR, Whittier M, Alam GL: Echocardiography. *Clin Tech Equine Pract* 3, 274-283, 2004.

9. Pipers FS, Hamlin RL: Echocardiography in the horse. *J Am Vet Med Assoc*, 170, 815-819, 1977.

10. Bakos Z, Voros K, Järvinen T, Reiczigel J: Two-dimensional and M-mode echocardiographic measurements of cardiac dimensions in healthy standardbred trotters. *Acta Vet Hung*, 50, 273-282, 2002.

11. Gehlen H, Haubold A, Stadler P: Reference values for echocardiographic parameters of trained and untrained Icelandic horses. *Dtsch Tierarztl Wochenschr*, 114, 374-377, 2007.

12. Meral Y, Bilal T: Yarış sezonundaki İngiliz ve Arap atlarında M-mod ekokardiyografik muayeneler. *Kafkas Univ Vet Fak Derg*, 13, 5-10, 2007.

13. Kaya M, Alkan Z, Kibar M, Şen Y, Acar A, Bumin A, Toker M: The Evaluation of echocardiographic findings on sports horses. *Kafkas Univ Vet Fak Derg*, 15, 751-757, 2009.

14. Stewart JH, Rose RJ, Barko AM: Echocardiography in foals from birth to three months old. *Equine Vet J*, 16, 332-341,1984.

15. Lombard CW, Evans M, Martin L, Tehrani J: Blood pressure, electrocardiogram and echocardiogram measurements in the growing pony foal. *Equine Vet J,* 16, 342-347, 1984.

16. Rovira S, Muñoz A: Two-dimensional-and m-mode echocardiographic measurements and indices of cardiac function in Spanish colts and fillies of different age. *J Vet Med Sci*, 71, 957-964, 2009.

17. Buhl R, Ersbøll AK, Eriksen L, Koch J: Changes over time in echocardiographic measurements in young Standardbred racehorses undergoing training and racing and association with racing performance. *J Am Vet Med Assoc*, 226, 1881-1887, 2005.

18. Gür NE: Atlarda yarış öncesi dönemde kalbin gelişimi, maksimal frekansı, ve koşu hızı ile atletik potansiyeli arasındaki ilişkinin incelenmesi. *Doktora tezi.* İstanbul Üniv Sağlık Bil Enst, 2010.

19. Patteson MW, Gibbs C, Wotton PR, Cripps PJ: Echocardiographic measurements of cardiac dimensions and indices of cardiac function in normal adult thoroughbred horses. *Equine Vet J Suppl,* 19, 18-27, 1995.

20. Dzudie A, Menanga A, Hamadou B, Kengne AP, Atchou G, Kingue S: Ultrasonographic study of left ventricular function at rest in a group of highly trained black African handball players. *Eur J Echocardiography*, 8,122-127, 2007.

21. Zucca E, Ferrucci F, Croci C, Di Fabio V, Zaninelli M, Ferro E: Echocardiographic measurements of cardiac dimensions in normal Standardbred racehorses. *J Vet Cardiol*, 10, 45-51, 2008.

22. Voros K: Quantitative two-dimensional echocardiography in the horse: A review. *Acta Vet Hung*, 45,127-36, 1997.

23. Haidar A, Farnir F, Deleuze S, Charlotte Sandersen C, Amory H: Comparison of the repeatability of echocardiographic measurements from different modes and views in horses of various breeds and sizes. *J Equine Vet Sci*, 30, 287-297 2010.

24. Helwegen MM, Young LE, Rogers K, Wood JL: Measurements of right ventricular internal dimensions and their relationships to severity of tricuspid valve regurgitation in national hunt thoroughbreds. *Equine Vet J Suppl*, 36, 171-177, 2006.

25. Voros K, Holmes JR, Gibbs: Measurement of cardiac dimensions with two-dimensional echocardiography in the living horse. *Equine Vet J*, 23, 461-465,1991.

26. Kayar A, **Gonul R**, **Or ME**, **Uysal A:** M-mode echocardiographic parameters and indices in the normal German shepherd dog. *Vet Radiol Ultrasound*, 47, 482-486, 2006.

27. Bertone JJ, Paull KS, Wingfield WE, Boon JA: M-mode echocardiographs of endurance horses in the recovery phase of long-distance competition. *Am J Vet Res*, 48, 1708-1712, 1987.

28. Pluim BM, Zwindermann AH, Van der Laarse A: The athlete's heart. A meta-analysis of cardiac structure and function.*Circulation*, 100, 336-344, 2000.

29. Grossman C, Grossman A, Koren-Morag N, Azaria B, Goldstein L, Grossman E: Interventricular septum thickness predicts future systolic hypertension in young healthy pilots. *Hypertension Res*, 31, 15-20, 2008.

30. Young L, Rogers K, Wood JLN: Left ventricular size and systolic function in thoroughbred racehorses and their relationships to race performance. *J Appl Physiol,* 99, 1278-1285, 2005.

31. Buhl RA: Review of structural features of the equine athlete's heart: Is a large heart an advantage for racing success. *Proceedings of the 54th Annual Convention of the American Association of Equine Practitioners*. San Diego: American Association of Equine Practitioners. 2008.

32. Opie LH: Overload hypertrophy and its molecular biology. **In,** Opie LH (Ed): Heart Physiology: From Cell to Circulation. pp. 391-418, Lippincott-Raven, Philadelphia, 1998.

33. Reichek N, Devereux RB: Reliable estimation of peak left ventricular systolic pressure by m-mode echographic determined end-diastolic relative wall thickness: Identification of severe valvular aortic stenosis in adult patients. *Am Heart J*, 103, 202-209, 1982.

34. Physick-Sheard PW: Cardiovascular response to exercise and training in the horse. *Vet Clin North Am: Equine Pract,* 1, 383-417, 1985.

35. Anderson B: Echocardiography: The normal examination and echocardiographic measurements. pp. 98-101, 2nd ed., MGA Graphic, Queensland, Australia, 2002.

36. Gehlen H, Marnette S, Rohn K Ellendorff F, Stadler P: Echocardiographic comparison of left ventricular dimensions and function after standardized treadmill exercise in trained and untrained healthy warmblood horses. *Equine Comp Exerc Physiol*, 3, 3-11, 2006.

37. Toker M, Sağmanlıgil V: Atlarda egzersiz öncesi ve sonrası sistolik ve diyastolik fonksiyonların doppler ekokardiyografi ile değerlendirilmesi. *Ankara Univ Vet Fak Derg,* 55, 7-12, 2008.

38. Schille S, Skrodzki M: M-mode echocardıographıc reference values in cats in the first three months of life. *Vet Radiol Ultrasound,* 40, 491-500, 1999.

39. Bayon A, Del Palacio JF, Montes AM, Gutierrez Panizo C: M-mode echocardiography study in growing Spanish mastiffs. *J Small Anim Pract*, 35, 473-479,1994.

40. Sampson SN, Jacobson RL, Sande RD, Susumi CJ, Larntz KJ, Tucker RL, Bayly WM: Reproducibility and repeatability of m-mode echocardiographic measurments collected from 25 normal horses. *J Vet Equine Sci,* 19, 51-57, 1999.