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# The Importance of Doppler-echocardiography in the Assessment of the Athlete's Heart

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## 1. Introduction

Summarizing observations of several authors characteristics of the athlete's heart can be divided into three groups:

- morphological characteristics, among which the most important modification of athlete's heart is a marked left ventricular (LV) hypertrophy,
- functional characteristics, which could mean better systolic and diastolic function and
- regulatory characteristics, a higher parasympathetic and a lower sympathetic activity at rest, resulting mostly in a lower heart rate, lower cardiac output, circumferential shortening velocity (Pavlik et al. 2010).

In the general medical practice LV hypertrophy is considered as a risk factor caused by some diseases as hypertension, obesity, cardiomyopathy, etc. To separate pathological and physiological hypertrophy the most important factors are functional and regulatory characteristics of the heart which can be mostly detected by Doppler-echocardiography.

## 2. The importance of Doppler-echocardiography in the distinguishing between physiologic and pathological left ventricular hypertrophy

### 2.1 Flow velocities

With the help of Doppler echocardiography the flow velocities and the time durations of different intervals can be estimated. The ratio between the early and late peak velocities (E/A) is linearly proportional to the diastolic function, i.e. to the ventricular distensibility. Data of different authors are in accordance that against the LV hypertrophy, E/A quotient does not decrease in athletes. Whether it is higher in athletes, or there is no difference between athletic and non-athletic groups, data are discordant. Based on different data and on our own investigations it seems that in young age, when diastolic function is perfect also in non-athletic subjects, regular physical training does not cause a marked improvement. If there is any, it is manifested in the male endurance athletes. It seems to be more probable; however, that regular physical activity attenuates the age-associated impairment of the diastolic function. A collection of data is shown in the Table 1.

AUTHORS	STUDY	RESULT
Shapiro, Smith 1983	different athletes	=
Granger et al. 1985	different athletes	=
Fagard et al. 1987	cycle racers	=
Missault et al. 1993	cycle racers	=
Pearson et al. 1986	weight lifters	=
Pavlik et al. 2001	children athletes	=
Pavlik et al. 1999a	women athletes	=
Vinereanu et al. 2001	power athletes	=
D'Andrea et al. 2007	power athletes	=
Perseghin et al. 2007.	different athletes	=
Teske et al. 2009.	different athletes	=
Matsuda et al. 1983	different athletes	+
Colan et al. 1985	different athletes	+
Douglas et al. 1986	triathlonists	+
Möckel et al. 1992	triathlonists	+
Finkelhor et al. 1986.	endurance athletes	+
Pavlik et al. 2001	different athletes	+
Vinereanu et al. 2001	runners	+
Rodrigues et al. 2006	6 months training	+
D'Andrea et al. 2007	endurance athletes	+
Spurgeon et al.1983	animal experiments	+
Starnes et al. 1983	animal experiments	+
Tate et al. 1990	animal experiments	+
Gwathmey et al. 1990	animal experiments	+
Schulman et al. 1992	older humans	=
Fleg et al. 1995	older humans	=
Sadaniantz et al. 1996	1 yr training in older humans	=
Baldi et al. 2003.	older humans	=
Teske et al. 2009.	older humans	=
Takemoto et al. 1992	older humans	+
Douglas, O'Toole 1992	older humans	+
Levy et al. 1993	6 months training in older humans	+
Pavlik et al. 2001	older humans	+
Galetta et al. 2004	older humans	+
Limongelli et al. 2006	older soccer players	+
Prasad et al. 2007	older humans	+

Table 1. Effect of regular physical training on the E/A quotient in different studies.  
= : physically trained hearts and non-trained hearts show similar values, + : physically trained hearts demonstrates an increased quotient

In our studies altogether 3076 subjects of different ages have been investigated since 1994 until now. The number of males was 1896 (non-athletic: 243, physically trained: 1653), number of females was 1180 (non-athletic 290, physically trained: 890). Results are shown in the Figure 1.

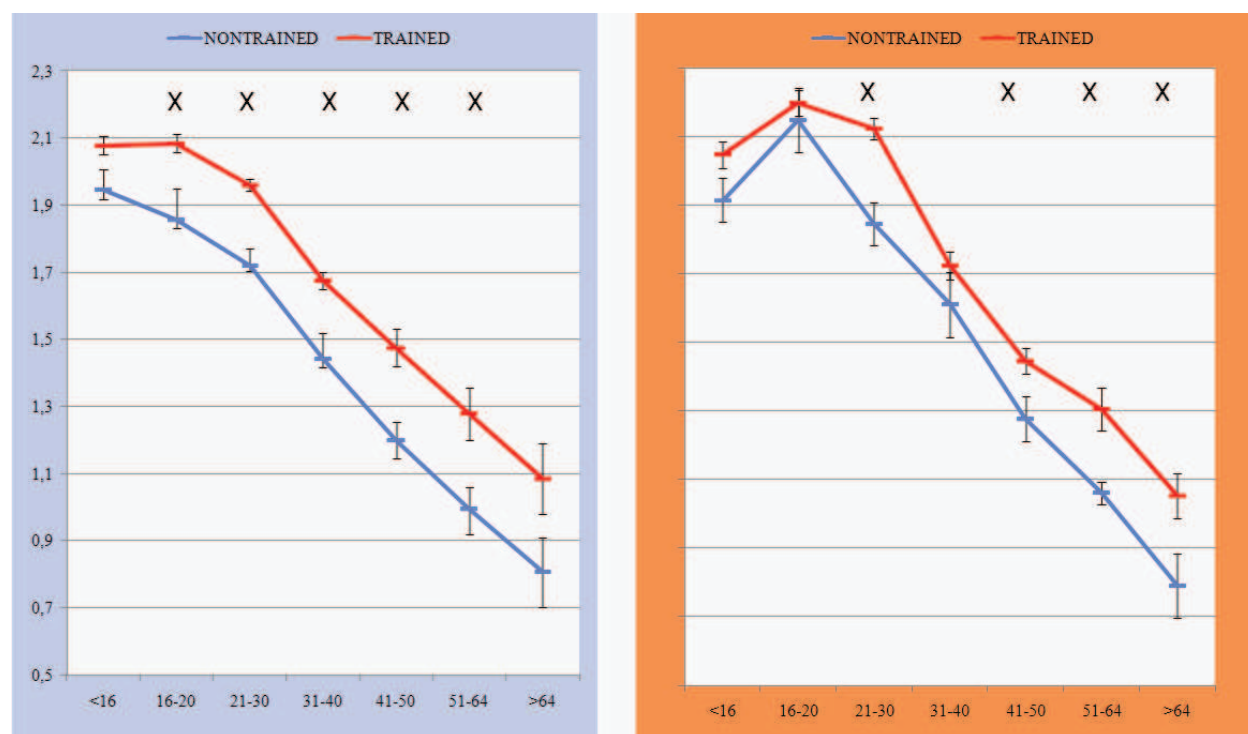


Fig. 1. The E/A quotient in the function of age in athletic (red lines) and non-athletic (blue lines) males (left graph) and females (right graph) (mean  $\pm$  s.e.m.). x: significant difference ( $p < 0.05$ )

Results are quite similar to those published in our older studies (Pavlik *et al.* 1999a, 1999b, 2001). In the younger groups LV distensibility is very good also in the non-athletic subjects; regular physical training does not induce a further improvement. In the adult and older groups E/A of the athletic groups is markedly higher than that of non-athletic groups.

In the evaluation of E/A it is disturbing that the quotient is inversely related to the heart rate: the higher is the heart rate, the lower is the E/A. The bradycardia of the athlete's heart is well known, sometimes it is very difficult to establish: the higher E/A of some athletic groups is a consequence of their lower heart rate, or it is an independent effect of the regular physical training. In our recent analysis heart rate dependent equations of the E/A quotient were compared between athletic and non-athletic subjects in different ages. It seems that in young subjects differences can be attributed to the frequency differences, while in older subjects the higher E/A is an independent effect of regular physical activity (Kneffel *et al.* 2011).

## 2.2 Cardiac cycle intervals

Bradycardia of the athlete's heart results significantly longer duration of the cardiac cycle in athletes than in non-athletes, there are, however, very few reports about the training

induced modifications of the different phases of the cardiac cycle. Doppler echocardiographic investigations help to reveal differences between the modifications of the different phases and sub phases. In our previous study (Pavlik *et al.* 1999b) in 221 male athletes and non athletes we made two main establishments.

1. There is one period, which is definitely increased in the athletes: it is the E-A period, i.e. the period of diastasis extending from the end of the early filling till the onset of the atrial systole.
2. The lengths of the two main cardiac phases are also different: the proportion of the systole is decreased in the athlete's heart.

Our further investigations confirmed the above mentioned establishments. Our data since 1994 until now are summarized in the Table 2 and 3. In this analysis data of different athletes were collected to common groups, in the tables data of 19-35 yr. old 846 males (62 non-athletes and 784 athletes) and 561 females (84 non-athletes and 477 athletes) are demonstrated.

Interval	Non-athletes		Athletes	
	Abs. (ms)	Rel. (%)	Abs. (ms)	Rel. (%)
ICT	41.2 ± 13.2	4.62 ± 1.58	<b>46.4 ± 19.7</b>	4.31 ± 1.78
AOAT	91.5 ± 18.6	10.37 ± 2.21	93.6 ± 16.5	<b>8.81 ± 1.75</b>
AODT	190.6 ± 20.4	21.28 ± 2.81	<b>205.7 ± 24.6</b>	<b>19.1 ± 2.69</b>
SYSTOLE	323.6 ± 30.0	36.28 ± 4.45	<b>345.5 ± 36.8</b>	<b>32.25 ± 4.22</b>
IVRT	77.9 ± 20.5	8.95 ± 2.55	<b>88.4 ± 21.6!</b>	<b>8.29 ± 2.11</b>
EACC	87.6 ± 14.3	9.81 ± 1.69	<b>95.7 ± 16.3</b>	<b>8.94 ± 1.72</b>
EDT	147.4 ± 42.0	16.06 ± 3.81	155.5 ± 34.6	<b>14.36 ± 3.18</b>
E-A	108.6 ± 82.3	11.30 ± 7.48	<b>233.5 ± 136.7</b>	<b>20.27 ± 9.50</b>
A	157.4 ± 36.1	17.60 ± 4.00	<b>169.6 ± 39.2</b>	<b>15.90 ± 4.06</b>
DIASTOLE	579.0 ± 109.9	64.2	<b>742.0 ± 154.1</b>	68.2
TOTAL	902 ± 121.4		<b>1087.5 ± 121.4</b>	

Table 2. Absolute and relative time durations of the cardiac cycle (mean ± s.d.) in 19-35 yr. old men. ICT: isovolumetric contraction time, AOAT: acceleratory phase of the aortic flow, AODT: deceleratory phase of the aortic flow (=decreased ejection), IVRT: isovolumetric relaxation time, EACC: acceleratory phase of the early transmitral flow (E), EDT: deceleratory phase of the early transmitral flow (E), E-A: a period from the end of the early transmitral flow (E) to the beginning of the atrial systole (A) (diastasis), A: atrial systole. Bold numbers: significant difference from the control values, where  $p < 0.05$

Interval	Non-athletes		Athletes	
	Abs. (ms)	Rel. (%)	Abs. (ms)	Rel. (%)
ICT	38.2 ± 11.9	4.46 ± 1.58	<b>43.7 ± 16.2</b>	4.19 ± 1.57
AOAT	87.6 ± 16.6	10.30 ± 2.22	<b>92.0 ± 15.9</b>	<b>8.92 ± 1.95</b>
AODT	198.3 ± 21.9	23.00 ± 3.20	<b>214.6 ± 22.2</b>	<b>20.5 ± 2.99</b>
SYSTOLE	325.9 ± 27.6	37.76 ± 4.98	<b>350.4 ± 30.8</b>	<b>33.61 ± 4.53</b>
IVRT	77.4 ± 18.5	9.18 ± 2.02	<b>85.8 ± 19.5</b>	<b>8.23 ± 2.01</b>
EACC	83.7 ± 14.7	9.65 ± 1.71	<b>91.6 ± 13.0</b>	<b>8.82 ± 1.70</b>
EDT	135.8 ± 30.6	15.18 ± 2.98	<b>155.0 ± 32.5</b>	14.69 ± 3.06
E-A	81.2 ± 73.8	8.58 ± 6.81	<b>207.4 ± 138.8</b>	<b>18.12 ± 9.85</b>
A	171.7 ± 42.9	19.65 ± 4.09	172.9 ± 39.9	<b>16.54 ± 4.04</b>
DIASTOLE	549.6 ± 111.1	62.8	<b>712.9 ± 161.4</b>	67.1
TOTAL	875.5 ± 117.9		<b>1062.5 ± 176.7</b>	

Table 3. Absolute and relative time durations of the cardiac cycle (mean ± s.d.) in 19-35 yr. old women. ICT: isovolumetric contraction time, AOAT: acceleratory phase of the aortic flow, AODT: deceleratory phase of the aortic flow (=decreased ejection), IVRT: isovolumetric relaxation time, EACC: acceleratory phase of the early transmitral flow (E), EDT: deceleratory phase of the early transmitral flow (E), E-A: a period from the end of the early transmitral flow (E) to the beginning of the atrial systole (A) (diastasis), A: atrial systole. Bold numbers: significant difference from the control values, where  $p < 0.05$

It is quite obvious that due to training bradycardia, the cardiac cycle of the athletes is longer. The contribution of the different phases can be seen on the tables. There is a basic difference in the elongation of the systole and of the diastole: systole is slightly (6.8 % in males, 7.5 % in females) longer in athletes, while the difference in the diastole is very definite (28.2 % and 29.7 % respectively).

The absolute duration of most of the subphases are a little longer in athletes. This increase can be attributed due to the resting bradycardia, but it is not proportional to the elongation of the whole cardiac cycle, the relative durations are decreased. There is only one period which shows a definite increase in absolute as well as in relative duration: E-A, i.e. the period from the end of the early phase to the beginning of late filling, when flow velocity is minimal or zero. This phase seems to be the most sensitive to the exercise training.

If we investigate the stability or variability of the different periods of the cardiac cycle, the ratio of the standard deviations to the mean absolute values can be calculated. Results are indicated in Table 4.

Period	Males		Females	
	non-athletes	athletes	non-athletes	athletes
ICT	32.0	42.5	31.1	37.1
AOAT	20.3	17.6	18.9	17.3
AODT	10.7	11.6	11.0	10.3
SYSTOLE	9.3	10.7	8.5	8.8
IVRT	26.3	24.4	23.9	22.7
EACC	16.3	17.0	17.6	14.2
EDT	28.5	22.3	22.5	21.0
E-A	75.8	58.5	90.9	66.9
A	22.9	23.1	25.0	23.1
DIASTOLE	19.0	20.8	20.2	22.6
TOTAL	13.5	11,2	13.5	16.6

Table 4. Ratio of the standard deviation to the mean value of different periods of the cardiac cycle in male and female subjects (s.d./mean)

Systole is more stable than diastole. Among the sub phases of the cardiac cycle in which an active flow is occurring are the most stable: AOAT, AODT, EACC, EDT. It is outstanding that the phase from the end of E to the beginning of A (E-A period) is very variable: its coefficient of variation is much higher than those of other periods.

The stability of systole is quite obvious: the pumping function, the ejection of the blood needs a rapid, abrupt contraction in any case, so it cannot be much longer even in case of the bradycardia of the athletic heart. All that means that training bradycardia arises from the elongation of diastole, which means a more economic cardiac function: longer relaxation time, more time for recovery and, as coronary circulation is free only during diastole, better coronary circulation.

Considering all cardiac phases, the greatest variability was seen in the period occurring between the end of the E and the beginning of the A phase, i.e. during which transmitral flow is practically minimal: the period of diastasis. This period is the most variable among all of the periods; the s.d./mean ratio of the absolute length is above 50 % in both groups. Thus, it seems that this is the period that can be modified to the greatest extent; training bradycardia seems to develop through elongation of this period.

Periods of the cardiac cycle seem to provide further data on the function and regulation of the athletic heart. Some data and some indices may widen the arsenal of the different signs characterising of the athlete's heart. Our data indicate that the E-A period, namely the

diastasis period of the diastolic filling is the most characteristic of the physically trained heart.

### 3. Tissue Doppler echocardiography

During the last two decades the used of the methods has been richer with the Tissue Doppler Imaging (TDI) technique. The main advantage of this method is that it offers direct measurements of local myocardial movements and velocities, it is less dependent on hemodynamic conditions and it makes also possible to establish wall movements at different segments of the heart. These advantages are used mostly in clinical cardiology for detailed investigations of some cardiac diseases or damages. The method has been introduced to the sports medicine as well. Several authors compared cardiac morphology, traditional Doppler and TDI indices of athletes to those of non-athletic healthy subjects and some cardiac patients (Caso *et al.* 2000, Vinereanu *et al.* 2001, Baldi *et al.* 2003, Galetta *et al.* 2004, Kasikcioglu *et al.* 2006, Rodrigues *et al.* 2006, D'Andrea 2007, Prasad *et al.* 2007, Caselli *et al.* 2009). An extensive review has been published recently (Krieg *et al.* 2007).

The main advantages of the TDI vs. traditional Doppler investigations in the sports medicine can be summarized as follows:

1. TDI results are less dependent on the heart rate than the traditional transmitral Doppler investigation findings (Caso *et al.* 2000, Baldi *et al.* 2003),
2. it offers a new index: ratio of the blood flow to tissue movement velocity ( $E/E'$ ) is inversely related to the LV filling pressure and hence, it is postulated to be lower in athletes (Baldi *et al.* 2003, Kasikcioglu *et al.* 2006),
3. it is not excluded that an enhanced systolic wall movement velocity ( $S'$ ) might show a better dynamic systolic function of the athletes heart (Baldi *et al.* 2003, Rodrigues *et al.* 2006, D'Andrea 2007).

During the last years we also made some investigations with TDI, our results are presented in the focus of the above mentioned three points.

1. Correlation coefficients between heart rate and the transmitral  $E/A$  and TDI determined  $E'/A'$  quotients were established in 19-35 yr old males and females (Table 5 and 6).

Heart rate / $E/A$	N	r	p
Transmitral $E/A$	144	<b>-0.305</b>	<b>&lt; 0.001</b>
Mitr. med. $E'/A'$	144	-0.090	> 0.2
Mitr. lat. $E'/A'$	144	-0.080	> 0.3
Tric. med. $E'/A'$	144	-0.068	> 0.4
Tric. lat. $E'/A'$	144	-0.130	> 0.1

Table 5. Correlation coefficients between heart rate and  $E/A$  quotients in 19-35 yr old males. E: early phase of the diastolic filling, A: late (atrial) phase of the diastolic filling,  $E'$ ,  $A'$ : TDI determined velocities



Heart rate / E/A	N	r	p
Transmitral E/A	44	<b>-0.366</b>	<b>&lt; 0.02</b>
Mitr. med. E'/A'	44	<b>-0.517</b>	<b>&lt; 0.001</b>
Mitr. lat. E'/A'	44	-0.181	> 0.2
Tric. med. E'/A'	44	-0.090	> 0.5
Tric. lat. E'/A'	44	-0.002	> 0.9

Table 6. Correlation coefficients between heart rate and E/A quotients in 19-35 yr old females

E: early phase of the diastolic filling, A: late (atrial) phase of the diastolic filling, E', A': TDI determined velocities

Results indicate that the disturbing effect of the heart rate is really stronger in case of the E/A, both in males and in females significant correlations were found. Relationship is much poorer with E'/A' values: it was only the mitral medial wall movement which correlated significantly with heart rate in women, the other r values were negative but not significant.

2. E/A, TDI determined E'/A', E/E' and S' values are indicated in the Table 7.

	Males		Females	
	Non athletes	Athletes	Non athletes	Athletes
E/A	<b>1.63 ± 0.34</b>	<b>1.93 ± 0.40</b>	<b>1.88 ± 0.55</b>	<b>2.08 ± 0.55</b>
Mitr. med. E'/A'	<b>1.56 ± 0.49</b>	<b>1.88 ± 0.62</b>	<b>1.54 ± 0.39</b>	<b>2.01 ± 0.60</b>
Mitr. med. E/E'	6.99 ± 1.27	7.48 ± 1.50	7.58 ± 1.12	7.77 ± 1.47
Mitr. med. S'	0.088 ± 0.013	0.088 ± 0.015	0.088 ± 0.015	0.084 ± 0.013
Mitr. lat. E'/A'	2.56 ± 0.59	2.69 ± 0.97	2.26 ± 0.68	2.43 ± 0.93
Mitr. lat. E/E'	5.76 ± 1.98	5.07 ± 2.07	6.30 ± 1.71	5.62 ± 1.47
Mitr. lat. S'	0.11 ± 0.030	0.12 ± 0.033	0.10 ± 0.015	0.12 ± 0.024
Tric. med. E'/A'	1.94 ± 0.21	2.01 ± 1.05	2.09 ± 1.06	2.05 ± 0.62
Tric. med. S'	0.094 ± 0.014	0.098 ± 0.026	0.088 ± 0.012	0.091 ± 0.013
Tric. lat. E'/A'	1.59 ± 0.86	1.65 ± 0.67	1.50 ± 0.36	1.94 ± 0.66
Tric. lat. S'	0.137 ± 0.022	0.140 ± 0.029	0.127 ± 0.021	0.131 ± 0.023

Table 7. Transmitral and TDI determined velocities and indices in 19-35 yr old male and females

E: early phase of the diastolic filling, A: late (atrial) phase of the diastolic filling, E', A': TDI determined velocities. S' systolic velocity. Bold numbers: significant difference from the control values where, p < 0.05

Significant differences were seen only in the E/A values and in the TDI measurements of the medial part of the mitral valve (med. E'/A'). If we examine other parameters in which differences were suggested by other authors, only some small, non-significant differences were seen. It is possible that by a refined selection restricted to top-level endurance athletes more significant differences could be found.

#### 4. Conclusion

Doppler echocardiography is a very important method in distinguishing physiologic hypertrophy from the pathologic one.

In this respect the most important point is the LV diastolic function. Commonly, the increase of the LV wall thickness and the LV muscle mass is associated with a decreased distensibility, an impaired diastolic function. In the athlete's heart despite of the LV hypertrophy an improved diastolic function can be detected either by transmitral or by TDI echocardiography.

Doppler echocardiography is also suitable to establish changes in the duration of the phases of the cardiac cycles. Training bradycardia results in a much more marked elongation of diastole than systole. Among the sub phases the E-A period i.e. the final phase of the diastole changes the most consequently, in the athlete's heart it will be longer.

#### 5. References

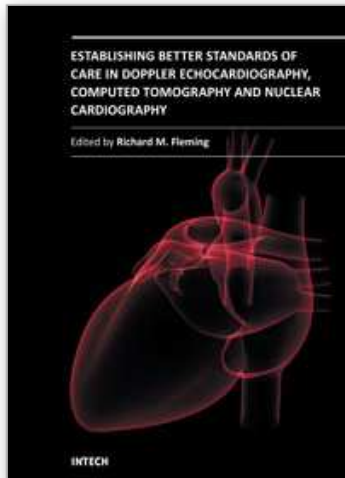
- [1] Baldi, J.C.; McFarlane, K.; Oxenham, H.C; Whalley, G.A.; Walsh, H.J.; Doughty, R.N. (2003). Left ventricular diastolic filling and systolic function of young and older trained and untrained men. *Journal of Applied Physiology*, Vol.95, No.6, (December 2003), pp. 2570-2575, ISSN 8750-7587
- [2] Caselli, L.; Galanti, G.; Padeletti, L.; Nieri, M.; Cecchi, F.; Cipollini, F.; Baldi, M.; Perrotta, L.; Vignini, S.; Michelucci, A. (2009). Diagnostic accuracy to extended-length electrocardiogram in differentiating between athlete's heart and hypertrophic cardiomyopathy. *Journal of Electrocardiology*, Vol.42, No.6, (July 2009) pp. 636-641, ISSN 1532-8430
- [3] Caso, P.; D'Andrea, A; Galderisi, M; Liccardo, B; Severino, S; De Simone, L.; Izzo, A; D'Andrea, L.; Minnini, N. (2000). Pulsed Doppler tissue imaging in endurance athletes: relation between left ventricular preload and myocardial regional diastolic function. *American Journal of Cardiology*, Vol.85, No.9, (May 2000) pp. 1131-1136, ISSN 0002-9149
- [4] Colan, S.D.; Sanders, S.P.; MacPherson, D.; Borow, K. (1985). Left ventricular diastolic function in elite athletes with physiologic cardiac hypertrophy. *Journal of American College of Cardiology*, Vol.6, No.3, (September 1985), pp. 545-549, ISSN 0735-1097
- [5] D'Andrea, A.; Caso, P.; Scarafile, R.; Salerno, G.; De Corato, G.; Mita, C.; Di Salvo, G.; Allocca, F.; Colonna, D.; Caprile, M.; Ascione, L.; Cuomo, S.; Calabró, R. (2007). Biventricular myocardial adaptation to different training protocols in competitive master athletes. *International Journal of Cardiology*, Vol.115, No.3, (February 2007), pp. 342-349, ISSN 1874-1754
- [6] Douglas, P.S.; O'Toole, M.L.; Hiller, D.B.; Reichek, N. (1986). Left ventricular structure and function by echocardiography in ultraendurance athletes. *American Journal of Cardiology*, Vol.58, No.9, (October 1986), pp. 805-809, ISSN 0002-9149

- [7] Douglas, P.S.; & O'Toole, M. (1992). Ageing and physical activity determine cardiac structure and function in the older athlete. *Journal of Applied Physiology*, Vol.72, No.5, (May 1992), pp. 1969-1973, ISSN 8750-7587
- [8] Fagard, R.H.; van den Broeke, C.; Bielen, E.; Vanhees, L.; Amery, A. (1987). Assessment of stiffness of the hypertrophied left ventricle of bicyclists using left ventricular inflow Doppler velocitometry. *Journal of American College of Cardiology*, Vol.9, No.6, (June 1987), pp. 1250-1254, ISSN 0735-1097
- [9] Finkelhor, R.S.; Hanak, L.J.; Behler, R.C. (1986). Left ventricular filling in endurance-trained subjects *Journal of American College of Cardiology*, Vol.8, No.8, (August 1986), pp. 289-293, ISSN 0735-1097
- [10] Fleg, J.L.; Shapiro, E.P.; O'Connor, F.; Taube, J.; Goldberg, A.P.; Lakatta, E.G. (1995). Left ventricular diastolic filling performance in older male athletes. *Journal of the American Medical Association*, Vol.273, No.17, (May 1995), pp. 1371-1375, ISSN 0077-8923,
- [11] Galetta, F.; Franzoni, F.; Femia, F.R.; Bartolomucci, F.; Carpi, A.; Santoro, G. (2004). Left ventricular diastolic function and carotid artery wall in elderly athletes and sedentary controls. *Biomedicine & Pharmacotherapy*, Vol. 58, No.8, (October 2004), pp. 437-442, ISSN 0753-3322
- [12] Granger, C.B.; Karimeddini, M.K.; Smith, V.E.; Shapiro, H.R.; Katz, A.M.; Riba, A.L. (1985). Rapid ventricular filling in left ventricular hypertrophy: I. Physiologic hypertrophy. *Journal of American College of Cardiology*, Vol.5, No.4, (April 1985), pp. 862-868, ISSN 0735-1097
- [13] Gwathmey, J.K.; Slawsky, M.T.; Perreault, C.L.; Briggs, G.M.; Morgan, J.P.; Wei, J.Y. (1990). Effect of exercise conditioning on excitation-contraction coupling in aged rats. *Journal of Applied Physiology*, Vol.69, No. 4, (October 1990), pp. 1366-1371, ISSN 8750-7587
- [14] Kasikcioglu, H.A.; Kasikcioglu, E.; Oflaz, H.; Unal, S.; Topcu, B.; Tartan. Z.; Arslan. A.; Cam, N.; Kayserilioglu, A. (2006). Discrimination between physiologic and pathologic left ventricular dilatation. *International Journal of Cardiology*, Vol.109, No.2, (May 2006) pp. 288-290, ISSN 1874-1754
- [15] Kneffel, Zs.; Varga-Pintér, B.; Tóth, M.; Major, Zs.; Pavlik, G. (2011) Relationship between the heart rate and E/A ratio in athletic and non-athletic males. *Acta Physiologica Hungarica*, In Press, ISSN 1588-2683
- [16] Krieg, A.; Scharhag, J.; Kindermann, W.; Urhausen, A. (2007). Cardiac tissue Doppler imaging in sports medicine. *Sports Medicine*, Vol.37, No.1, (2007), pp. 15-30, ISSN 0112-1642
- [17] Levy, W.C.; Cerqueira, M.D.; Abrass, I.B.; Schwartz R.S. ; Stratton J.R. (1993). Endurance exercise training augments diastolic filling at rest and during exercise in healthy young and older men. *Circulation*, Vol.88, (1993), pp. 116-126, ISSN 0009-7322
- [18] Limongelli, G.; Verrengia, M.; Pacileo, G.; Da Ponte, A.; Brancaccio, P.; Canonico, R.; D'Andrea, A.; Sarubbi, B.; Cerasuolo, F.; Calabró, R.; Limongelli, F.M. (2006). Left ventricular hypertrophy in Caucasian master athletes: differences with hypertension and hypertrophic cardiomyopathy. *International Journal of Cardiology*, Vol.111, No.1, (July 2006), pp. 113-119, ISSN 1874-1754

- [19] Matsuda, M.; Sugishita, Y.; Koseki, S.; Ito, I.; Akatsuka, T.; Takamtso, K. (1983). Effect of exercise on left ventricular diastolic filling in athletes and non-athletes. *Journal of Applied Physiology*, Vol.55, No.2, (August 1983), pp. 323-328, ISSN 8750-7587
- [20] Missault, L.; Duprez, D.; Jordaens, L.; Buyzere, M.de.; Bonny, K.; Adang, L.; Clement, D. (1993). Cardiac anatomy and diastolic filling in professional road cyclists. *European Journal of Applied Physiology*, Vol.66, No.5, (1993), pp. 405-408, ISSN 1439-6319
- [21] Möckel, M.; Störk, T.; Müller, R.; Eichstadt, H.; Hochrein, H. (1992). Left ventricular diastolic function in triathletes and untrained subjects: A stress Doppler-echo study. *Perfusion*, Vol.5, (1992), pp. 69-74,
- [22] Pavlik, G.; Olexó, Zs.; Bánhegyi, A.; Sidó, Z.; Frenkl, R. (1999a). Gender differences in the echocardiographic characteristics of the athletic heart. *Acta Physiologica Hungarica*, Vol.86, No.3-4 (October 1999), pp. 273-278, ISSN 1588-2683
- [23] Pavlik, G.; Olexó, Zs.; Osváth, P.; Sidó, Z.; Frenkl, R. (2001). Echocardiographic characteristics of male athletes of different age. *British Journal of Sports Medicine*, Vol.35, No.2, (April 2001), pp. 95-99, ISSN 1473-0480
- [24] Pavlik, G.; Olexó, Zs.; Sidó, Z.; Frenkl, R. (1999b). Doppler-echocardiographic examinations in the assessment of the athletic heart. *Acta Physiologica Hungarica*, Vol.86, No.1, (1999), pp. 7-22, ISSN 1588-2683
- [25] Pavlik, G.; Major, Zs.; Varga-Pintér, B.; Jeserich, M.; Kneffel, Zs. (2010). The athlete's heart. *Acta Physiologica Hungarica*, Vol.97, No. 4, (December 2010), pp. 337-353, ISSN 1588-2683
- [26] Pearson, A.C.; Schiff, M.; Mrosek, D.; Labovitz, A.J.; Williams, G.A. (1986). Left ventricular diastolic function in weight lifters. *American Journal of Cardiology*, Vol.58, No.13. (December 1986), pp. 1254-1259, ISSN 0002-9149
- [27] Perseghin, G.; De, Cobelli, F.; Esposito, A.; Lattuada, G.; Terruzzi, I.; La, Torre, A.; Belloni, E.; Canu, T.; Scifo, P.; Del, Maschio, A.; Luzi, L.; Alberti G. (2007). Effect of the sporting discipline on the right and left ventricular morphology and function of elite male track runners: A magnetic resonance imaging and phosphorus 31 spectroscopy study. *American Heart Journal*, Vol.154, No.5, (November 2007), pp. 937-942, ISSN 0002-8703
- [28] Prasad, A.; Popovic, ZB.; Arbab-Zadeh, A.; Fu, Q.; Palmer, D.; Dijk, E.; Greenberg, N.L.; Garcia, M.J.; Thomas, J.D.; Levine, B.D. (2007). The effects of aging and physical activity on Doppler measures of diastolic function. *American Journal of Cardiology*, Vol.99, No.12, (June 2007), pp. 1629-1636, ISSN 0002-9149
- [29] Rodrigues, A.C.T.; Melo, Costa, J.; Alves, G.B.; Silva, F.; Picard, M.H.; Andrade, J.L.; Mathias, W.; Negrão, C.E. (2006). Left ventricular function after exercise training in young men. *American Journal of Cardiology*, Vol.97, No.7, (April 2006), pp. 1089-1092, ISSN 0002-9149
- [30] Sadaniantz, A.; Yurgalevitch, S.; Zmuda, J.M.; Thompson, P.D. (1996). One year of exercise training does not alter resting left ventricular systolic or diastolic function. *Medicine and Science in Sports and Exercise*, Vol.28, No. 11, (November 1996), pp. 1345-1350, ISSN 0195-9131
- [31] Schulman, S.P.; Lakatta, E.G.; Fleg, J.L.; Lakatta, L.; Becker, L.C.; Gerstenblith, G. (1992). Age-related decline in left ventricular filling at rest and exercise. *American Journal of Physiology*, Vol.263, No. 6, (December 1992), pp. H1932-H1938, ISSN 0363-6127

- [32] Shapiro, L.M. & Smith, R.G. (1983). Effect of training on left ventricular structure and function: an echocardiographic study. *British Heart Journal*, Vol.50, No.6, (November 1983) pp. 534-539, ISSN 0007-0769
- [33] Spurgeon, H.A.; Steinbach, M.F.; Lakatta, E.G. (1983). Chronic exercise prevents characteristic age-related changes in rat cardiac contraction. *American Journal of Physiology*, Vol.244, No.4, (April 1983) pp. H513-H518, ISSN 0363-6127
- [34] Starnes, J.W.; Beyer, R.E.; Edington, D.W. (1983). Myocardial adaptations to endurance in aged rats. *American Journal of Physiology*, Vol.245, No.4, (October 1983), pp. H560-H566, ISSN 0363-6127
- [35] Takemoto, K.A.; Bernstein, L.; Lopez, J.F.; Marshak, D.; Rahimtoola, S.H.; Chandraratna, P.A.N. (1992). Abnormalities of diastolic filling of the left ventricle associated with ageing are less pronounced in exercise trained individuals. *American Heart Journal*, Vol.124, No.1, (July 1992), pp. 143-148, ISSN 0002-8703
- [36] Tate, C.A.; Taffet, G.E.; Hudson, E.K.; Blaylock, S.L.; McBride, R.P.; Michael, L.H. (1990). Enhanced calcium uptake of cardiac sarcoplasmic reticulum in exercise-induced old rats. *American Journal of Physiology*, Vol.258, No.2, (February 1990), pp. H431-H435, ISSN 0363-6127
- [37] Teske, A.J.; Prakken, N.H.; De Boeck, B.W.L.; Velthuis, B.K.; Doevendans, P.A.; Cramer, M.J.M. (2009). Effect of long term and intensive endurance training in athletes on the age related decline in left and right ventricular diastolic function as assessed by Doppler echocardiography. *American Journal of Cardiology*, Vol.104, No.8, (October 2009), pp. 1145-1151, ISSN 0002-9149
- [38] Vinereanu, D.; Florescu, N.; Sculthorpe, N.; Tweddel, A.C.; Stephens, M.R.; Fraser, A.G. (2001). Differentiation between pathologic and physiologic left ventricular hypertrophy by tissue Doppler assessment of long-axis function in patients with hypertrophic cardiomyopathy or systemic hypertension and in athletes. *American Journal of Cardiology*, Vol.88, No.1, (July 2009), pp. 53-58, ISSN 0002-9149

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