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Research article

MYOCARDIAL PERFORMANCE AND AORTIC ELASTIC PROPERTIES IN ELITE BASKETBALL AND SOCCER PLAYERS: RELATIONSHIP WITH AEROBIC AND ANAEROBIC CAPACITY

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ABSTRACT

The aims of the present study were to examine the myocardial performance index and aortic elastic properties of athletes engaged in ball sports and to determine their relationships with aerobic and anaerobic characteristics. Standard M-mode and Doppler echocardiography, maximal oxygen uptake and 30 sec Wingate tests were performed for 32 elite male athletes (12 basketball and 20 soccer players) and 12 healthy sedentary volunteers. Data were analyzed by ANOVA and partial correlation coefficient tests. Absolute values of left ventricular internal diameter, left ventricular posterior wall and interventricular septum thicknesses in diastole were significantly ($p < 0.05-0.01$) greater in athletes than in controls. The left ventricular internal diameter corrected by body surface area was also greater ($p < 0.05-0.01$) in the athletes compared with the controls. Absolute and body surface area corrected left ventricular mass were significantly greater ($p < 0.05-0.001$) in athletes than in controls. Isovolumetric relaxation time was higher ($p < 0.01$) in soccer players than in controls. There were no significant differences among the groups for myocardial performance index and aortic elastic properties. Left ventricular mass index was poorly correlated ($p < 0.01$) with VO_2max ($r = 0.410$), peak power ($r = 0.439$) and average power ($r = 0.464$) in the athletes. Poor correlations ($r = 0.333-0.350$, $p < 0.05$) were also observed between aortic elastic properties and average power in athletes. Myocardial performance index and aortic elastic properties are not different in athletes involved in this study compared with sedentary subjects. Aerobic and anaerobic capacities of the athletes used in this study are poorly explained by these resting echocardiographic findings.

KEY WORDS: Athletes' heart, cardiac function, aortic elastic properties, oxygen uptake, power.

INTRODUCTION

A meta-analysis study (Pluim, et al., 1999) and a review (Fagard, 1997) article revealed that the left ventricular systolic and diastolic function is normal in the athlete at rest, whereas diastolic function seems to be enhanced in the performing endurance athlete. According to the results of the echocardiographic studies conducted in basketball and soccer players, there are no differences in resting left ventricular systolic function compared with sedentary subjects (Samauroo et al. , 2001; Van Decker et al., 1989). On the other hand, improved diastolic functions in soccer players were also reported (Muir et al., 1999; Sozen et al., 2000). In the above mentioned studies systolic and diastolic functions were evaluated by several different parameters such as transmitral flow ratio (E/A) and ejection fraction (EF). For better understanding of the left ventricular resting heart function, Tei (1995), Poulsen et al. (2000) and Moller et al. (1999) suggested to calculate the myocardial performance index. They reported that the myocardial performance index had a narrow range in healthy subjects, it was easy to obtain and reproduce, and independent of heart rate, of blood pressure, of ventricular geometry, of afterload and preload. To our knowledge, however, there is only one existing data regarding myocardial performance index of athletes in the literature (Kasikcioglu et al., 2003). According to this study, endurance training had a positive effect on myocardial performance index. However, cardiovascular adaptation in endurance athletes is different from ball-trained athletes. Independently from technical training/skills, training in ball sports (e.g., soccer and basketball) involves dynamic (both aerobic and anaerobic) and static exercises which leads to a combination of eccentric and concentric enlargement in athletes' heart (Fagard, 1997; Muir et al., 1999).

One of the important determinant of left ventricular function is the aortic elastic properties those which also correlate with oxygen uptake (VO_2) (Rerkpattanapipat et al., 2002). A decrease in exercise capacity in healthy older population was revealed to be associated with age-related increase in arterial stiffness (Vaitkevicius et al., 1993). Endurance trained male athletes, aged between 54 to 75 years, also displayed significantly reduced arterial stiffness indices relative to their sedentary age peers (Vaitkevicius et al., 1993). Reduced aortic distensibility in elite power athletes (in wrestlers) than in healthy control was reported (Kasikcioglu et al., 2004). In contrast, Erol et al. (2002) reported increased aortic distensibility by prolonged training in top-level athletes including runners, wrestlers, boxers and basketball players. However, aortic elastic properties of athletes engaged in ball sports have not been fully investigated to date.

The aim of this study was, therefore, to examine the myocardial performance index and aortic elastic properties of the elite ball sports' athletes by echocardiography, and to determine their relationships with aerobic and anaerobic characteristics of the athletes.

METHODS

Subjects

A total of 32 Caucasian elite male athletes (12 basketball and 20 soccer players) and 12 healthy male sedentary controls voluntarily participated in the study. Soccer and basketball players were members of the National Soccer and Basketball Premier League clubs, respectively. The control subjects were recruited from healthy members of the hospital staff who were not exercising regularly. The characteristics of the subjects are presented in Table 1. None of the subjects had any cardiac and/or vascular diseases on the basis of negative medical history, physical examination, and electrocardiogram. None of the subjects were receiving any medication, and they were normotensive and nonsmoker. Training backgrounds for last 12 months were determined according to declarations made by the team coaches. On average, the basketball players trained 13 hours per week which was comprised of 8 hours of specific basketball training, 1 hour of strength training, 2 hours of aerobic/endurance activities, 1 hour of anaerobic dynamic training, and 1 hour of balance and coordination exercises. Soccer players had, on average, 10 hours of weekly training which included; 6 hours specific soccer training, 2 hours anaerobic dynamic training,1 hour strength training and 1 hour aerobic endurance activities.

Table 1. Physical characteristics of athletes and controls. Data are means (± SD).

	Basketball players (n=12)	Soccer players (n=20)	Controls (n=12)
Age (years)	22 (5)	24 (4)	24 (2)
Height (cm)	198 (8) ***,†††	178 (5)	176 (4)
Weight (kg)	96 (10) ***,†††	74 (6)	69 (8)
Body Surface area (m^2)	2.3 (.2) ***,†††	1.9 (.1)	1.8 (.1)
Heart rate ($beat \cdot m^{-1}$)	62 (10) †††	62 (6) †††	78 (10)
Systolic blood pressure (mm·Hg)	118 (11)	118 (10)	112 (11)
Diastolic blood pressure (mm·Hg)	76 (7)	75 (7)	74 (5)
Pulse Pressure (mm·Hg)	42 (9)	43 (10)	38 (9)
Training age (years)	8 (4) **	11 (4)	-
VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	64 (5) **,†††	56 (9) †††	42 (3)
Peak Power ($watt \cdot kg^{-1}$)	12.3 (1.0) †††	12.3 (1.2) †††	9.6 (1.4)
Average power ($watt \cdot kg^{-1}$)	8.7 (.6) †††	8.7 (.5) †††	7.5 (.8)

** $p < 0.01$ and *** $p < 0.001$ compared with soccer players.
††† $p < 0.001$ compared with controls.

The subjects participated in the study after being informed about testing procedures, possible risks and discomfort, and subsequently providing signed informed consent in accordance with the Helsinki Declaration (WMADH, 2000).

Procedure

All tests were applied to athletes on consecutive three days following the pre-seasonal training. Physical examination, echocardiographic evaluation, a maximal oxygen uptake test and an anaerobic power test (Wingate test) were performed respectively. Concurrently, the controls were also were subjected to the same protocol.

Echocardiography

The echocardiographic evaluation was performed by the same experienced cardiologist on every occasion using HP Sonos 2000 (USA) with a 2.25 MHz transducer in left lateral position following the recommendations of the American Society of Echocardiography (Sahn et al., 1978). Images were obtained in the parasternal long and short axis and in the apical two and four chamber views. From a concomitant ECG, left ventricular internal diameter (LVID), left ventricular posterior wall thickness (LVPWT) and interventricular septum thickness (IVST) in diastole and systole were digitized at the peak of the R wave by the average of 3 cardiac cycles. The ascending aorta was recorded in the two-dimensional guided M-mode tracings. Aortic diameters were recorded 3cm above the aortic valve. Aortic systolic diameter was determined at the time of the full opening of the aortic valve, and aortic diastolic diameter was determined at the peak of QRS. Blood pressure was measured simultaneously with a mercury sphygmomanometer. Korotkoff phases I and V of the measurements were used to determine the systolic and diastolic blood pressure. Pulse pressure was calculated as systolic minus diastolic blood pressure.

Pulsed-wave Doppler measurements of mitral inflow were obtained with the transducer on the four-chamber view. A 1–2 mm Doppler sample volume was placed between the tips of the mitral leaflets during diastole. The left ventricular outflow velocity curve was recorded from the apical long-axis view with the sample volume positioned just below the aortic valve. Doppler velocities and time intervals were measured from mitral inflow and left ventricular outflow recordings. Isovolumetric relaxation time (IVRT) was the time interval from cessation of left ventricular outflow to onset of mitral inflow, ejection time (ET) was the time interval from the onset and cessation of left ventricular outflow, and mitral early diastolic flow; deceleration time (DT) was the time interval between the peak E velocity and the end of the early diastolic flow. Total systolic time interval was measured from the cessation of one mitral flow to the beginning of the following mitral inflow. Isovolumetric contracting time (ICT) was calculated by subtracting ET and IVRT from the total systolic time interval. The ratio of velocity time intervals of mitral early peak (E) and late peak (A) diastolic flows (E/A) was calculated. Ejection fraction (EF) of the left ventricle was calculated by using modified Simpson's technique.

Calculations

For individual differences in anthropometric data the absolute cardiac measures were corrected by body surface area as previously recommended (Pavlik et al., 1996). Square root of body surface area was more appropriate for linear numerators (wall thickness, diameters), while for weights the cube of the square root of body surface area were used.

- Left ventricular mass (LVM) was calculated using the method described by Devereux et al. (1986):

$$LVM = 1.04 \times [(LVIDd + IVSTd + PWTd)^3 - LVIDd^3] - 13.6$$

LVIDd = left ventricular internal end-diastolic dimension, IVSTd = interventricular septal thickness, and PWTd = posterior wall diastolic thickness. Furthermore, left ventricular mass index was calculated by dividing LV mass by body surface area.

- Aortic strain was calculated as follows (Stefanidis et al., 1990):

$$AS = (AoS - AoD) / AoD$$

AoS = systolic aortic diameter and AoD = diastolic aortic diameter.

- Aortic distensibility was calculated as follows (Stefanidis et al., 1990):

$$\text{Aortic distensibility: } 2 \times (AoS - AoD) / (AoD \times PP)$$

PP = pulse pressure.

- The aortic stiffness index was calculated as follows (Stefanidis et al., 1990):

$$\text{Aortic stiffnes index} = \ln (SBP / DBP) / [(AoS - AoD) / AoD]$$

SBP = systolic blood pressure and DBP = diastolic blood pressure.

- The myocardial performance index (MPI) was calculated by using the formula (Tei, 1995):

$$MPI = (IVRT + ICT) / ET$$

IVRT = isovolumetric relaxation time, ICT = isovolumetric contraction time and ET = ejection time.

• Relative wall thickness in diastole (RWTd) was calculated according to the following formula, in order to classify the type of hypertrophy:
RWTd = 2 x PWTd / LVIDd

Four patterns of left ventricular geometry were defined based on an upper normal limit for LVMI of 124 $g·m^{-2}$ and RWTd of 0.44, according to previously defined criteria (Tomiyama et al., 1996): (1) concentric hypertrophy (increased LVMI and RWTd); (2) eccentric hypertrophy (increased LVMI and normal RWTd); (3) concentric remodeling (normal LVMI and increased RWTd); and (4) normal geometry (normal LVMI and normal RWTd).

Maximal oxygen uptake test
An incremental treadmill test (Woodway, Germany) until exhaustion was performed to determine maximal oxygen uptake (VO_2 max) following a 5 minute warm-up. The inclination of treadmill was 2.5% and was increased every three minutes by 2.5 %. Speed was steady and 10 km per hour. Ventilatory parameters were continuously measured breath- by- breath using a metabolic analyzer (SensorMedics 2900C system, USA) during maximal test. The criteria for achieving VO_2max was evaluated as a heart rate within ± 10 beats·min^{-1} of the age related maximum (220-age in years), a ventilatory equivalent for O_2 (minute ventilation / O_2 uptake) close to 30 L·min^{-1} and respiratory exchange ratio (RER) greater than 1.15 (Sekir et al., 2002). All tests met these criteria.

Wingate anaerobic test
Subjects performed a 30-s Wingate test on a cycle ergometer (Monark 817 E, Sweden). They were allowed for a warm-up period including jogging, cycling and stretching. At the onset of the test, the load was set at 0.075 g/kg. Subjects were verbally encouraged to pedal as fast and hard as they could until they were instructed to stop. Anaerobic peak power and average power were calculated using the Monark 1.0 software program (Sweden).

Statistical analysis
Data are expressed as the mean ± standard deviation (SD). For comparison among the groups, one way analysis of variance (ANOVA) was used. Scheffe' post hoc test was performed to evaluate a significant *F*-value. To avoid a mutual association with the other variables, partial correlation coefficient test was used in order to assess the relationships between selected variables. Statistical significance was accepted for $p < 0.05$.

RESULTS

Selected physical characteristics of the three groups are shown in Table 1. Height, weight and the body surface area of the basketball players were significantly different than the soccer players and controls. Although basketball players were slightly younger than controls and soccer players there was no significant difference amongst. Resting heart rate, aerobic and anaerobic capacities were significantly different in athletes than in controls. In addition, the aerobic capacity was higher in basketball players compared to soccer players. The training age was greater in the soccer players than the basketball players.

The echocardiographic dimensions are shown in Table 2. Absolute values of left ventricular internal diameter, left ventricular posterior wall and interventricular septum thickness in diastole were significantly greater in the athletes than the controls.

Table 2. Cardiac structure in athletes and controls. Data are means (±SD).

	Basketball players (n=12)	Soccer players (n=20)	Controls (n=12)
LVIDd (mm)	58 (5) **,†††	52 (4) †	48 (4)
LVIDd·$BSA^{-1/2}$ (mm·m^{-1})	38 (3) †	38 (3) †	35 (2)
LVPWTd (mm)	10 (2) †	10 (1) ††	9 (1)
LVPWTd·$BSA^{-1/2}$ (mm·m^{-1})	7 (1) *	8 (1) ††	6 (1)
IVSTd (mm)	11 (2) ††	11 (2) †	9 (2)
IVSTd·$BSA^{-1/2}$ (mm·m^{-1})	7 (1)	8 (1) †	6 (1)
LVM (g)	304 (68) †††	261 (52) †††	175 (43)
LVMI (g·m^{-2})	132 (25) †††	137 (24) †††	94 (17)
LVM·$BSA^{-3/2}$ (g·m^{-3})	87 (16) †	99 (17) †††	69 (11)
RWTd	.35 (.07)	.40 (.06)	.36 (.06)

* $p < 0.05$ and ** $p < 0.01$ compared with soccer players.
† $p < 0.05$, †† $p < 0.01$ and ††† $p < 0.001$ compared with controls.
LVIDd = left ventricular internal end-diastolic dimension, IVSTd = interventricular septum diastolic thickness, PWTd = posterior wall diastolic thickness, LVM = left ventricular mass, LVMI = left ventricular mass index and RWTd = relative end-diastolic wall thickness.

Table 3. Doppler echocardiography measurements. Data are means (±SD).

	Basketball players (n=12)	Soccer players (n=20)	Controls (n=12)
Diastolic			
Peak E ($m·s^{-1}$)	.73 (.18)	.85 (.13)	.84 (.13)
Peak A ($m·s^{-1}$)	.41 (.08) *,††	.52 (.11)	.55 (.08)
E/A ratio	1.79 (.35)	1.71 (.27)	1.56 (.31)
DT (msec)	162 (26)	182 (52)	146 (33)
IVRT (msec)	90 (11)	95 (20) ††	78 (13)
Systolic			
EF (%)	59 (5) ***	75 (6) †††	64 (6)
ICT (msec)	30 (8)	33 (15)	38 (9)
ET (msec)	298 (24) *	275 (19)	285 (32)
MPI	.30 (.08)	.36 (.09)	.37 (.09)

* $p < 0.05$ and *** $p < 0.001$ compared with soccer players.
†† $p < 0.01$ and ††† $p < 0.001$ compared with controls.
E = early passive filling of left ventricle, A = late atrial contraction filling of left ventricle, DT = deceleration time, IVRT = isovolumetric relaxation time, EF = ejection fraction, ICT = isovolumetric contraction time, ET = ejection time and MPI = myocardial performance index.

The left ventricular internal diastolic diameter corrected by body surface area was also higher in the athletes than the controls. Corrected values of left ventricular posterior wall thickness and interventricular septum thickness in diastole were significantly higher in soccer players. Absolute and body surface area related left ventricular mass of the ball players were significantly greater. A heterogeneous pattern of left ventricular geometry was observed in soccer players (nine subjects with eccentric hypertrophy, six subjects with concentric hypertrophy, four with normal geometry and one with concentric remodeling). However, the basketball players displayed a more homogeneous pattern of left ventricular geometry (seven subjects with eccentric hypertrophy, four with normal geometry, and one with concentric hypertrophy). Eleven of the controls had normal ventricular geometry, and one displayed eccentric hypertrophy.

Doppler measurements are shown in Table 3. Despite lower transmitral late peak flow velocity in basketball players than the soccer players and the controls, the transmitral peak flow ratio revealed no significant difference among the groups. Although, isovolumetric relaxation time was higher in athletes, only the value of soccer players reached a significant level. No significant differences detected among the groups in deceleration time and isovolumetric contraction time. Ejection time was not different between soccer players and controls, but significantly longer in basketball players compared with soccer players. The myocardial performance index value, which reflects the global ventricular function, was lower in athletes, but not significantly different among the groups.

Only the aortic stiffness index of the soccer players was slightly increased when compared with controls but there were no significant differences in the other aortic elastic properties among the groups (Table 4).

Table 5 and 6 display partial correlation coefficients between aerobic and anaerobic properties with left ventricular structure, function and aortic elastic properties in all subjects and in three groups, respectively. Left ventricular mass index showed moderate correlation with aerobic and anaerobic properties in total group (athletes and control subjects together), and low correlation with

Table 4. Aortic elastic properties in athletes and controls. Data are means (±SD).

	Basketball players (n=12)	Soccer players (n=20)	Controls (n=12)
Systolic aortic diameter (mm)	30 (5)	28 (3)	27 (3)
Systolic diameter index ($mm·m^{-1}$)	20 (3)	21 (2)	20 (2)
Diastolic aortic diameter (mm)	27 (5)	26 (3)	25 (3)
Diastolic diameter index ($mm·m^{-1}$)	18 (3)	19 (2)	18 (2)
Aortic distensibility ($mm·Hg^{-1}·10^{-3}$)	4.58 (1.52)	3.96 (1.96)	5.13 (1.52)
Aortic stiffness index	4.85 (1.36)	6.95 (3.49) †	4.56 (1.68)
Aortic strain	.10 (.04)	.08 (.04)	.10 (.03)

† $p < 0.05$ compared with controls

Table 5. Partial correlation coefficients (r) between aerobic and anaerobic properties with myocardial performance index (MPI), aortic elastic properties and LVM·BSA$^{-3/2}$ in total group (athletes and control subjects together, n = 44).

	VO_2 max	Peak Power	Average Power
LVM·BSA$^{-3/2}$	.410 **	.439 **	.464 **
MPI	-.157	.054	-.099
Aortic distensibility	.003	.217	.333 *
Aortic stiffness index	.103	.189	.350 *

* $p < 0.05$ and ** $p < 0.01$
LVM = left ventricular mass, BSA = body surface area.

peak power in controls. There were low correlations between aortic elastic properties and average power in total group. There were no significant relationship between myocardial performance index and aerobic /anaerobic properties.

DISCUSSION

In summary, the results of this study showed that; 1) left ventricular internal diameter, left ventricular posterior wall and interventricular septum thicknesses in diastole, and left ventricular mass were significantly greater in athletes than in controls, 2) there were no remarkable differences in Doppler velocities and time intervals among the groups, 3) the myocardial performance index was not significantly different among the groups, 4) there were no significant differences among the groups for aortic elastic properties, and 6) left ventricular mass index and aortic elastic properties were poorly correlated with aerobic and anaerobic parameters.

It was agreed that soccer and basketball players had greater left ventricular wall thickness, internal diameter and mass compared to those of controls (Muir et al., 1999; Sozen et al., 2000; Van Decker et al., 1989). Our results regarding left ventricular cavity, thickness and cardiac mass in basketball and soccer players were consistent with above mentioned studies.

Studies conducted on athletes engaged in ball (Pela et al., 2004; Van Decker et al., 1989), endurance and power sports (Pluim et al. 1999) revealed no significant differences in systolic function at rest. In the present study, the ejection fraction of soccer players was greater than that of basketball players and controls. On the other hand, the ejection time of soccer players was shorter that of basketball players. One of the reasons for these contradictory results might be extremely larger body surface area of the basketball players. The other could be relatively greater aortic stiffness index and lower aortic distensibility observed in soccer players, which affects the afterload. Diastolic functions of the athletes who took part in this study were slightly improved compared with controls. Similar to our results, other studies in ball players reported such improvements (Muir et al., 1999; Sozen et al., 2000) or no changes (Pela et al., 2004;

Table 6. Partial correlation coefficients (r) between aerobic and anaerobic properties with myocardial performance index (MPI), aortic elastic properties and LVM·BSA$^{-3/2}$ in different groups.

	VO_2 max	Peak Power	Average Power
Controls (n=12)			
LVM·BSA$^{-3/2}$	.249	.711*	.631
MPI	.162	.156	-.031
Aortic distensibility	.533	.294	.631
Aortic stiffness index	.415	.129	.565
Basketball players (n=12)			
LVM·BSA$^{-3/2}$	-.111	-.244	.364
MPI	-.125	-.452	-.395
Aortic distensibility	-.019	.352	.235
Aortic stiffness index	.057	.338	.158
Soccer players (n=20)			
LVM·BSA$^{-3/2}$	-.051	-.053	-.135
MPI	-.146	.226	.098
Aortic distensibility	.046	.194	.334
Aortic stiffness index	.284	.165	.439

* $p < 0.05$
LVM = left ventricular mass, BSA = body surface area.

Van Decker et al., 1989) in some of the indices of diastolic function. However, myocardial performance index, which is independent of heart rate, of blood pressure, of ventricular geometry etc., was suggested for better clarification of the left ventricular resting heart function in athletes. Moller et al. (1999) have defined the normal range of myocardial performance index as 0.34±0.04 in healthy volunteers. It was 0.30±0.08, 0.36±0.09 and 0.37±0.09 for basketball players, soccer players and healthy controls, respectively, in the present study. However, there were not statistically significant differences amongst. This might imply that our subjects have normal resting left ventricular function despite differences in cardiac cycle times and left ventricular hypertrophy. Kasikcioglu et al. (2003) evaluated myocardial performance index in endurance athletes, and stated that myocardial performance index was 0.28±0.07 and 0.46±0.11 for endurance athletes and sedentary subjects, respectively. However, myocardial performance index value for sedentary subjects observed in their study was greater than the normal range defined by Moller et al. (1999). It was also similar to the value (0.45±0.08) reported for the patients who have < 50% coronary stenosis (Dagdelen et al., 2002). We could not discuss our data considering Kasikcioglu et al. (2003) results, since they did not report full details. Moreover, we did not observe such a significant difference between athletes and healthy controls, thus, it can be concluded that myocardial performance index might be different between the athletes regarding their training backgrounds/levels.

Except slightly greater aortic stiffness index in soccer players than in controls, there were no differences in the parameters of aortic elastic properties among the groups of athletes and sedentary controls. Similar to our study, Alessandri et al. (1995) did not find significant differences in the elasticity-stiffness parameters of major vessels in senior athletes versus military young men. In contrast, an improvement in aortic distensibility was reported for the athletes by the study of Erol et al. (2002), in which, the group of athletes was chosen from various disciplines (14 runners, 5 wrestlers, 4 boxers, and 5 basketball players). Using a mixed group of athletes is limiting to interpret the effects of training backgrounds on the function of heart and vessels. It is also limiting to compare their data with the results of the present study. However, in a study of Kingwell et al. (1995) involving athletes with undefined athletic activity background notified a better systemic arterial compliance whereas Bertovich et al. (1999) involving strength-trained athletes was reported a decrement in arterial compliance. Kasikcioglu et al. (2004) also indicated a decrement in aortic elastic properties in elite power athletes compared with sedentary healthy subjects. They suggested that increased stiffness in elite power athletes, who trained by >60% of weight lifting in their training program over than 7 years, represents the mechanical signal of ventricular wall stress which was compensated by the development of ventricular hypertrophy. These changes were attributed to cardiovascular adaptation to habitual isometric exercises. However, possible undeclared steroid usage makes their results controversial, considering long-term anabolic steroid usage might result in premature atherosclerosis (Madea et al., 1998) and this might lead to reduction in arterial compliance (Dart et al., 1991). In addition, cardiac structures of athletes involved in above mentioned studies were different. For instance, the athletes in the study of Kasikcioglu et al. (2004) had a concentric hypertrophy as a result of training, whereas the athletes involved in the present study had mainly eccentric hypertrophy. In the light of the previous and our findings it might be suggested that to use specific athletic group instead of mixed or undefined groups would be more appropriate to interpret the effects of different athletic activities on aortic elastic properties. It would also be favorable for comparison of the results with others.

The relationship between left ventricular mass and VO_2 max in endurance athletes as described by Osborne et al. (1992) was not observed in older endurance athletes (Child et al., 1984). Cubero et al. (2000) reported a moderate correlation (r = 0.6741) between left ventricular mass and VO_2 max in junior soccer players but not in cyclists (r = 0.2273) and in canoeists (r = 0.1741). However, the relationship for total group was poor with a *'r'* value of 0.4727 in the study of Cubero et al., similar to the *'r'* value (0.410) observed for total group in the present study. In addition, Cubero et al. have used a simple correlation test whereas we preferred partial correlation to avoid a mutual association with the other variables in order to assess the relationships between selected variables. We also observed poor positive correlations between left ventricular mass and peak power, and average power for total group. When three groups were separately analyzed these relationships were disappeared. This may be result of the similar training volume of the athletes involved in the groups, which may lead to narrow ranges of cardiac, aerobic and anaerobic findings. Kasikcioglu et al. (2003) and Libonati et al. (2001) reported inverse correlations between VO_2 max and myocardial performance index in endurance athletes, and between peak treadmill time and myocardial performance index in healthy subjects, respectively. Our findings are inconsistent with the results of these studies. However, the training background of athletes in the study of Kasikcioglu et al. (2003) is different than our subjects'. Similarly, in the study of Libonati et al. (2001), testing parameter (peak treadmill running time as a nonobjective method of aerobic capacity), gender of subjects (18 males and 33 females), testing protocol (Bruce protocol) are different than the present study. Therefore, contradictory results between the studies might be related to the differences in the subjects' training backgrounds, tested parameters, gender and testing protocols.

In available literature, there were no data which seeks the relationships between aerobic-anaerobic parameters and aortic elastic properties in athletes. In older patients, however, with dilated cardiomyopathy (Bonapace et al., 2003) and systolic heart failure (Rerkpattanapipat et al., 2002), the aortic elastic properties were reported as an important predictor of VO_2. Vaitkevicius et al. (1993) reported an age-related decrease in exercise capacity in healthy people associated with the age-related increase in arterial stiffness. They also reported significantly reduced arterial stiffness in endurance trained male athletes, aged between 54 to 75 years, compared with healthy sedentary age peers. In the present study, the subjects were young and have normal aortic elastic properties. This may explain why the results of the present study are different than the studies mentioned above.

Soccer and basketball trainings include dynamic anaerobic component (e.g. sprints, fast-breaks, jumping etc.) in addition to aerobic component. According to our knowledge, this is the first study which investigates anaerobic parameters and cardiac functions in athletes. Our data indicated that there are poor correlations between anaerobic indices (peak power and average power) and left ventricular mass in total group (athletes and controls together) as seen for VO_2 max. Additionally, non-significant correlations were observed between anaerobic indices and myocardial performance index and between anaerobic indices and aortic elastic properties in total group and in each group of athletes. Furthermore, moderate correlations between left ventricular mass and peak power ($r = 0.711$), and average power ($r = 0.631$) were observed for healthy controls. The challenging explanation for these findings might be to some extent related to the influence of genetics. However, further comprehensive studies are needed to explain the underlying matters satisfactorily.

CONCLUSIONS

Results of this study indicate that myocardial performance index and aortic elastic properties are not different in athletes involved in this study compared with sedentary subjects. Aerobic and anaerobic parameters of athletes used in this study are poorly explained by resting echocardiographic characteristics. VO_2 max and anaerobic power indices are variables that better determines left ventricular mass developed in ball sport specific training. Further investigation with greater number of subjects from different activity backgrounds and different gender is required to establish the function of heart and vessel. In addition, it needs dynamic echocardiographic evaluation to demonstrate the relationships between cardiac function and aerobic/anaerobic capacity of athletes.

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KEY POINTS

- Left ventricular internal diameter, left ventricular posterior wall and interventricular septum thicknesses in diastole, and left ventricular mass were significantly greater in athletes than in controls.
- There were no remarkable differences in Doppler velocities and time intervals between athletes and controls.
- Myocardial performance index and aortic elastic properties are not different in athletes compared with sedentary subjects.
- Aerobic and anaerobic parameters of athletes are poorly explained by resting echocardiographic characteristics.
- VO_2 max and anaerobic power indices are variables that better determines left ventricular mass developed in ball sport specific training.

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