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Echocardiographic characteristics in adolescent junior male athletes of different sport events

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The purpose of this study was to examine the effects of different sport activities on cardiac adaptation. Echocardiographic data of 137 athletes and 21 non-athletes were measured and compared in two age groups 15–16 and 17–18 years of age. Athletes belonged into three groups according to their sports activity (endurance events, power athletes, ball game players). The observed variables were related to body size by indices in which the exponents of the numerator and the denominator were matched.

Left ventricular hypertrophy was manifest in all athletic groups. Power athletes had the largest mean left ventricular wall thickness (LVWTd) in both age groups. In the older age group differences between the athletic groups were smaller, but the endurance and power athletes had significantly higher wall thickness. Left ventricular internal diameter (LVIDd) was the largest in the endurance athletes, while mean relative muscle mass (LVMM) was the largest in the power athletes. LVMM of the older endurance athletes was significantly larger. Muscular quotient (MQ) was the highest in the endurance athletes; in the 17–18-year group there was no inter-event difference. Bradycardia was most manifest in the endurance athletes and ball game players, power athletes had higher resting heart rates than non-athletic subjects. It can be inferred that endurance training induces firstly an enlargement of the left ventricle what is then followed by an increase of muscle mass. In the studied functional and regulatory parameters no difference was found between the athletic and non-athletic groups.

Keywords: junior athletes, athlete’s heart, echocardiography, power events, endurance events, ball games

It has been well established that regular physical activity associates with a number of morphological and functional changes of the heart (1, 3, 16, 20, 31, 32). However, conflicting results have been reported concerning the life period when such cardiac adaptation becomes demonstrable during biological maturation. Some studies (33, 36) failed to find any echocardiographic difference between athletic and non-athletic groups in prepuberty; while other authors (11, 12, 17, 21, 22, 28) reported on a morphological adaptation of the heart at the early age of 10 to 14 years. Forster et al. (8) and

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Mesko et al. (18) observed in a longitudinal study of 10- to 15-year old athletes that the characteristics of the athlete's heart only appeared after two years of systematic exercise training of appropriate intensity, indeed significant differences from the non-athletic groups could only be evidenced after the third or even the fourth year of training.

Reports on junior athletes are relatively scarce. Sharma et al. (35) could notice differences between the athletic and non-athletic 14–18-year-old subjects in the left ventricular wall thickness, left ventricular internal diameter and left ventricular muscle mass, however there was no difference in the body size related wall thickness. In young athletes aged 15 to 18 Pavlik et al. (25, 26) and Manolas et al. (15) showed evidence for the positive effects of regular physical activity on the development of the athlete's heart. However, we know only few studies about the influence of the different sport events on the cardiac adaptation of this age group. Although several authors have approved of a classification of cardiac adaptation into categories of concentric- or eccentric type hypertrophy (5, 13, 14, 32), the degree of this hypertrophy in young athletes is still an open question concerning the various physical activities.

The first aim of the present study was to examine the effects of various sport events on the morphology and functionality of the heart in 15- to 18-year old male athletes, and the second one was to understand the changes in cardiac adaptation with age.

Subjects and Methods

Material

137 junior male athletes and 21 non-athletes were measured (Tables I and II). The athletic subjects were top-level performers of their age category who engaged in physical activity at least nine to fifteen hours a week and had a strong athletic history of a minimum of three, but mostly five years. They were divided in two age groups, 15–16-year-old subjects formed the first group and 17–18-year-old ones the second.

Sport events were classified in three groups according to the type of exercise. The group of endurance athletes consisted of 2 top class swimmers, 3 long and middle distance runners, 4 road cyclists, 6 kayak canoeists and 8 triathletes. The power athletes were 16 weight lifters and a karate competitor. The ball game players were players of soccer (n = 12), basketball (n = 18), water polo (n = 66) and tennis (n = 1). Twenty-one non-athletic subjects served as controls.

Echocardiography

Cardiac function was measured by a two dimensionally guided M-mode and Doppler Dornier AI 4800 echocardiograph, with a 2.5 MHZ transducer, in recumbent position always during the morning hours. The measurements were carried out in accordance with the recommendations of the American Society of Echocardiography (34). In all subjects three to five cardiac cycles were measured and then means were calculated for the further analysis.

Table I

General data of the subjects in the age group of 15–16 years (mean ± SD)

	N	Age (year)	Height (cm)	Weight (kg)	BSA (m^2)*
Endurance athletes (END)	11	15.3 (0.50)	179.13 (5.39)	67.54 (8.06)	1.85 (0.13)
Power athletes (PWA)	7	15.8 (0.37)	166.14 (12.13)	71.57 (26.86)	1.78 (0.37)
Ball game players (BGP)	41	15.6 (0.48)	188.93 (6.89)	75.59 (14.11)	2.02 (0.18)
Non-athletic (NA)	11	15.1 (1.04)	175.81 (8.61)	63.47 (11.25)	1.77 (0.18)
Total	70				

*BSA: Body Surface Area; calculated from body height and body weight (4).

Table II

General data of the subjects in the age group of 17–18 years (mean ± SD)

	N	Age (year)	Height (cm)	Weight (kg)	BSA (m^2)*
Endurance athletes (END)	12	17.7 (0.48)	178.83 (7.46)	69.58 (6.50)	1.87 (0.12)
Power athletes (PWA)	10	17.4 (0.51)	170.13 (8.79)	74.35 (18.10)	1.84 (0.24)
Ball game players (BGP)	56	17.4 (0.50)	187.41 (7.46)	77.03 (16.62)	2.03 (0.20)
Non-athletic (NA)	10	17.6 (0.51)	176.09 (7.13)	76.25 (13.51)	1.92 (0.19)
Total	88				

*BSA: Body Surface Area; calculated from body height and body weight (4).

Based on reports by several authors and our own observations (9, 10, 24, 26, 27) body size related indices were calculated by indices in which the exponents of the numerator and the denominator were matched. Wall thickness and internal diameter were therefore related to the square root of body surface area (BSA), while left ventricular muscle mass and volumes were related to the cube of the square root of BSA. Transmitral flow velocity was estimated by pulse wave Doppler measurements in the four chamber apical view.

The measured variables and their calculation were as follows:

IVSTd = interventricular septum thickness at end diastole

LVPWTd = left ventricular posterior wall thickness at end diastole

LVWT = left ventricular wall thickness (IVSTd + LVPWTd)

$LVWT/BSA^{1/2}$ = body size related left ventricular wall thickness at end diastole

LVIDd = left ventricular internal diameter at end diastole

$LVIDd/BSA^{1/2}$ = body size related left ventricular internal diameter at end diastole

LVMM = left ventricular muscle mass as ($TEDD^3$-EDV)•1.053 where

TEDD = left ventricular diameter at end diastole (LVWT+LVIDd),

EDV = left ventricular volume at end diastole ($LVIDd^3$),

1.053 = density of the cardiac wall.

$LVMM/BSA^{3/2}$ = body size related left ventricular muscle mass

MQ = muscular quotient (LVWT/LVIDd)

FS = fractional shortening, 100•(LVIDd-LVIDs)/LVIDd where

LVIDs = left ventricular internal diameter at systole

SV = stroke volume ($LVIDd^3$–$LVIDs^3$)
SV/$BSA^{3/2}$ = body size related stroke volume
CO = cardiac output (SV▪HR)
CO/$BSA^{3/2}$ = body size related cardiac output
E/A = ratio of early to late diastolic filling
HR = heart rate

Statistical analysis

Means and standard deviations are tabulated. Event groups were compared by using ANOVA, for intragroup differences we used post-hoc analysis (Tukey). Age group comparisons were made by using *t*-tests for independent data. Differences of at least $p<0.05$ were regarded as significant. StatSoft, Inc. (2001), Statistica software system, version 6.0 was used for data analysis.

Results

Absolute values of morphological data

Signs of left ventricular hypertrophy were noticed in all athletic groups (Table III). In both age groups the wall thickness of the non-athletic subjects was smaller than in the athletic subjects. Among the younger athletes LVWT was the largest in the power athletes, while in the older group we measured the largest values in the ball game players.

In both age groups LVIDd was the largest in the ball game players. Non-athletic subjects differed significantly from the endurance athletes and ball game players. At 17–18 years ball game players had significantly larger values than power athletes.

LVMM was larger in all the athletic groups than in the non-athletic group for both groups of age. In the younger group the power athletes had a non-significantly larger muscle mass than the endurance athletes; however in the older group the reverse was found. None of the differences between the athletic groups of either age were significant. Older endurance athletes had a significantly larger LVMM compared to the younger age group.

Muscular quotient was the highest in the power athletes of both age groups. At 15–16 years the mean of the power athletes was significantly higher than in the endurance athletes and non-athletic subjects. The latter two did not differ. At 17–18 years there was no difference between the groups. The quotient in the endurance athletes of this age was remarkably higher than in the younger ones. For the other athletic subjects no difference was found.

Body size related morphological data

In the younger group the exponent corrected body size related LVWT was again the largest in the power athletes, the ball game players and endurance athletes followed them (Table IV). The non-athletic groups had significantly lower values than the athletic groups. The difference between the endurance and power athletes was significant. In the older group these differences were larger. In respect of the two age groups relative wall thickness was the same for the power athletes, but it was significantly higher in the older endurance athletes and ball game players.

In both age groups body size related LVIDd was significantly larger only in the endurance athletes compared to the non-athletic group. Body size related LVMM was significantly larger in all athletic subjects. In the younger age group the largest values were measured in power athletes, while in the older age group endurance athletes had the highest values; power athletes had even lower values than ball game players.

Functional and regulatory parameters

The endurance athletes and ball game players of 15–16 years showed a definite bradycardia. Both the non-athletic subjects and power athletes had significantly higher heart rates (Table V). In the older group mean resting heart rate was lower in both the ball game players and power athletes, but their difference remained significant. The power athletes had an even higher heart rate than the non-athletic subjects. At this age the ball game players had the lowest cardiac frequency.

Fractional shortening percentage indicating the quality of the systolic function of the heart was the same for all subjects of 15–16. However, for the older year age group the ball game players showed a significantly higher percentage than the power athletes.

Diastolic function was monitored by the quotient of E/A, i.e. the quotient of the early and late diastolic filling. The non-athletic subjects tended to show lower values than athletic ones, but these differences were not significant.

Body size related resting stroke volume was the largest in the endurance athletes of both age groups (Table VI). The latter group and the ball game players differed slightly from the non-athletic subjects at the age of 17–18.

Exponent corrected body size related resting cardiac output was significantly larger in the power athletes than in the ball game players. The older power athletes had a smaller relative output than the younger ones.

Discussion

Our aims in this study were to establish the effects of various sport activities on the morphology and function of the heart, to follow the changes in the cardiac adaptation process through the age groups, and to investigate the signs of a possible eccentric- or concentric type hypertrophy (5, 13, 25, 29).

Corroborating to other studies (15, 23, 35) left ventricular hypertrophy was manifest in our athletic population already at the age of 15–16 years. At the age of 17–18 differences between the athletic and non-athletic subjects still existed or in some aspects became even more marked.

Table III

Morphological data of the left ventricle (mean ± SD)

	AG	END (E)	PWA (P)	BGP (B)	NA (N)	p < 0.05	p < 0.01	p < 0.001
IVSTd (mm)	15–16	8.93 (0.83)	9.92 (1.55)	9.92 (1.02)	7.70 (0.85)	E>N		P,B>N
	17–18 ##	10.36 (1.22)	9.85 (1.23)	10.32 (1.28)	8.97 (0.86)	E,B>N		
LVPWtd (mm)	15–16	8.94 (0.93)	9.83 (1.87)	9.61 (1.03)	7.95 (1.04)		P>N	B>N
	17–18 #	9.97 (1.14)	9.87 (1.21)	10.08 (1.03)	8.72 (0.97)	E>N	B>N	
LVWT (mm)	15–16	17.88 (1.49)	19.76 (3.38)	19.54 (1.89)	15.66 (1.78)			P,B>N
	17–18 ##	20.34 (2.15)	19.72 (2.35) #	20.41 (2.13)	17.70 (1.66)	E>N	B>N	
LVIDd (mm)	15–16	51.76 (2.54)	49.40 (5.52)	52.09 (3.59)	46.07 (4.31)		E>N	B>N
	17–18	52.50 (2.57)	48.93 (5.16)	52.78 (4.21)	48.26 (4.69)	**B>P**, B>N		
LVMM (g)	15–16	209.68 (21.08)	232.55 (104.22)	240.46 (45.42)	147.64 (39.10)	E>N	P>N	B>N
	17–18 #	257.56 (63.66)	223.52 (68.82)	261.82 (60.61)	186.60 (43.41)	E>N	B>N	
MQ (%)	15–16	35.65 (3.96)	39.80 (2.51)	37.65 (4.20)	34.08 (3.28)	**E<P**		
	17–18 ##	38.72 (3.24)	40.39 (3.51)	38.79 (4.13)	36.88 (3.92)	B,P>N		

IVSTd: interventricular septum thickness at diastole; LVPWtd: left ventricular posterior wall thickness at diastole; LVWT: left ventricular wall thickness; LVIDd: left ventricular internal diameter at diastole; LVMM: left ventricular muscle mass; MQ: muscular quotient.
AG: age group; END (E): endurance athletes; PWA (P): power athletes; BGP (B): ball game players; NA (N): non-athletic subjects.
#: $p < 0.05$, ##: $p < 0.01$, significant difference compared to the 15–16 years old age group.
Bold: significant difference between athletic groups.

Table IV

Body size related morphological data of the left ventricle (mean ± SD)

	AG	END (E)	PWA (P)	BGP (B)	NA (N)	p < 0.05	p < 0.01	p < 0.001
LVWT/$BSA^{1/2}$	15–16	13.16 (1.22)	14.81 (1.38)	13.76 (1.23)	11.76 (1.19)	**P > E**		P,B > N
(mm/m)	17–18 ##	14.86 (1.55)	14.53 (1.19) #	14.35 (1.39)	12.78 (1.01)	P > N	E,B > N	
LVIDd/$BSA^{1/2}$	15–16	38.09 (1.94)	37.18 (1.99)	36.72 (2.68)	34.63 (3.12)	E > N		
(mm/m)	17–18	38.35 (1.91)	36.07 (2.61)	37.12 (2.89)	34.80 (2.10)	E > N		
LVMM/$BSA^{3/2}$	15–16	83.81 (11.09)	94.91 (18.47)	84.12 (16.57)	62.43 (14.63)	E > N		P,B > N
(g/m^3)	17–18 #	100.38 (20.67)	87.87 (16.75)	90.84 (19.50)	69.37 (9.41)		E,B > N	

LVWT/$BSA^{1/2}$: body size related left ventricular wall thickness; LVIDd/$BSA^{1/2}$: body size related left ventricular internal diameter at diastole; LVMM/$BSA^{3/2}$: body size related left ventricular muscle mass.
AG: age group; END (E): endurance athletes; PWA (P): power athletes; BGP (B): ball game players; NA (N): non-athletic subjects.
#: $p < 0.05$, ##: $p < 0.01$, significant difference compared to the 15–16 years old age group.
Bold: significant difference between athletic groups.

Table V

Functional and regulatory echocardiographic data (mean ± SD)

	AG	END (E)	PWA (P)	BGP (B)	NA (N)	p < 0.05	p < 0.01	p < 0.001
HR (beats*min^{-1})	15–16	61.83(11.13)	80.48 (14.54)	62.13 (9.99)	75.22 (12.70)	E > N	**P > E**, B > N	**P > B**
	17–18	61.36 (6.90)	71.11 (10.11) #	57.42 (9.55)	67.85 (8.69)		B > N	**P > B**
FS (%)	15–16	34.89 (3.86)	34.59 (3.26)	36.50 (4.78)	35.77 (3.42)			
	17–18	34.59 (3.76)	31.24 (5.27)	36.47 (4.13)	35.26 (4.34)		**B > P**	
E/A	15–16	1.99 (0.47)	2.17 (0.42)	2.23 (0.61)	1.76 (0.42)			
	17–18	2.23 (0.66)	2.31 (0.41)	2.11 (0.41)	1.84 (0.37)			

HR: heart rate; FS: fractional shortening; E/A: proportion of the early and late diastolic filling peak velocity.
AG: age group; END (E): endurance athletes; PWA (P): power athletes; BGP (B): ball game players; NA (N): non-athletic subjects.
#: $p < 0.05$ significant difference compared to the 15–16 years old age group.
Bold: significant difference between athletic groups.

Table VI

Body size related functional and regulatory echocardiographic data (mean ± SD)

	AG	END (E)	PWA (P)	BGP (B)	NA (N)	p < 0.05	p < 0.01	p < 0.001
$SV/BSA^{3/2}$	15–16	40.26 (7.60)	37.45 (7.54)	37.12 (8.42)	31.12 (8.56)			
(ml/m^3)	17–18	40.70 (6.41)	35.03 (7.49)	38.63 (9.81)	30.88 (6.05)			
$CO/BSA^{3/2}$	15–16	2.53 (0.92)	3.07 (0.99)	2.29 (0.57)	2.32 (0.67)	P > B		
($l/min \cdot m^3$)	17–18	2.49 (0.43) #	2.22 (0.41)	2.23 (0.86)	2.10 (0.53)			

$SV/BSA^{3/2}$: body size related stroke volume; $CO/BSA^{3/2}$: body size related cardiac output.
AG: age group; END (E): endurance athletes; PWA (P): power athletes; BGP (B): ball game players; NA (N): non-athletic subjects.
#: $p < 0.05$ significant difference compared to the 15–16 years old age group.
Bold: significant difference between athletic groups.

As shown by some studies (25, 30) in adults, static exercise does not necessarily result in concentric hypertrophy that is, in a more intense increase of LVWT compared to LVIDd. In agreement with other studies (2, 7), we also found some marks for concentric-type hypertrophy at 15–16 years of age. Power athletes had the highest MQ values. In the age group of 17–18 years smaller differences between the athletic groups were noted. During the early phase of adaptation the effects of static exercise on the development of concentric-type hypertrophy seem to be more manifest. At an older age further exercise results in a better-balanced adaptation.

At the age of 17–18 years, MQ differences between the examined groups were different from those observed in the younger age. There were no intragroup differences and significantly higher means were seen in the older endurance athletes. The reason for this "late" increase is probably due to the fact that in the present study nearly 50% of the younger endurance athletes had a shorter athletic history, namely an average of three to four years, when the mean of the athletes was six to seven years. A few years of athletic history seems to have been insufficient to induce significant modifications in the heart in our study. At 17–18 years, cardiac morphologic dimensions of the endurance athletes seem to approach or even exceed the values of the other athletes, though the signs of an eccentric- or concentric type hypertrophy cannot be clearly distinguished.

Our results confirm results of our previous investigations (28) where we found that endurance type dynamic exercise had led first to an enlargement of the left ventricular cavity diameter and then to the development of muscle mass (LVMM).

Of the functional and regulative parameters, heart rate shows most markedly the effects of regular physical training. Indeed, preferable effects of a dynamic type exercise, such as a lower heart rate were more often found in the sports events, in which dynamic exercise training dominated. Bradycardia attributable to regular physical exercise was manifest in both the endurance athletes and ball game players throughout the studied age range (15 to 18 years). Possible exercise effects on the other functional indices studied were less clearly established in the athletic groups.

The ratio of E/A did not show any differences during this period of life. As reported before (7, 19, 25, 26) regular physical activity, especially endurance activity lead to a better compliance, but these effects manifest itself in older age. It is not surprising that exercise training effects have not been detected in the young ones.

Resting SV, resting CO and FS% are influenced by several factors (e.g. innervation of the left ventricle, seasonal changes in physical condition), therefore it is of small wonder that differences in these parameters were not significant at this young age.

It was concluded that the studied sport events had a different effect on the development of myocardial adaptation to exercise. However, the sequence of age-dependent changes in the morphology and functionality of the heart requires further study.

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