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Echocardiographic Study of Cardiac Structure in Cyclists and Runners

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ABSTRACT: We sought to study the cardiac morphology of cyclists and runners in male and female athletes and control subjects and to find association cardiac morphological measurements with body composition measurements. Endurance training is associated with increases in both left ventricular mass (LVM) and left ventricular end-diastolic dimension (LVEDD). Cardiac morphology shows sports specific adaptations which are studied in the two groups, runners involving lower limb and cyclists involving upper limb. 28 runners and 26 cyclists were taken to do a comparison study with 38 control subjects, aged between 18-25 years of age and comprising of males and females both. All participants underwent transthoracic echocardiography and hydrostatic underwater weighing for body composition along with routine measurements. Athletes showed enlarged LV dimensions and mass ($p<0.05$) as compared to controls. Right ventricular and aortic root dimensions were also found to be significantly higher in athletes ($p<0.05$). Lean tissue mass was found to be independent predictor of LVM. Increased LV wall thickness in relation to the ventricular dimension appears to be proportionate in runners; it is disproportionate in cyclists, probably because of the isometric training component involved during upper limb training cycling. Hence runners show eccentric hypertrophy and cyclist showed mixed eccentric and concentric hypertrophy. LVM was found to be correlated only to lean tissue mass. The extent of LV remodeling (athletic heart) in trained individuals may reflect a normal physiologic response to increased lean tissue mass induced by training.

Key words: Echocardiography, hydrostatic underwater weighing, left ventricular mass, lean tissue mass.

INTRODUCTION

Athlete's heart term is used to describe a variety of alterations in the cardiac structure of athletes engaged in different sports. Morganroth et al in 1975 were the first to postulate that 2 different morphological forms of athlete's heart can be distinguished i.e. a strength trained heart and an endurance trained heart [1]. According to their theory, isometric training results in a more concentric hypertrophy which is characterized by an increase in left ventricle (LV) thickness where as isotonic training results in more prominent enlargement of LV diameter. But abundant literature [2-4] has been unable to resolve satisfactorily the question regarding the existence of 2 types of athlete's heart. Regular participation in sports causes such changes w hich depend on the amount and intensity of training [5]. Some studies [6,7] has supported the fact and some [8 -10] has not found clear demarcating evidence. However, differences in echocardiographic indices between marathon runners, cyclists and triathletes have been reported of suggesting sports specific cardiac adaptations [11]. Furthermore, it has been suggested that the cardiac changes to endurance training depends on the group of muscles involved whether lower or upper. Cycling and long distance running are two predominantly endurance sports involving isotonic exercises. Cycling also involves isometric work of the upper body for efficient performance while running involves mainly isotonic exercises of the lower body.

Both LV size and LV mass (LVM) are related to body size [12-15] and are often divided by body surface area (BSA) to determine normal ranges and to detect the presence of pathologic LV hypertrophy [16-17]. However this method has been found to have shortcomings as it overestimates LV hypertrophy in lean subjects and underestimates in obese individuals. In non athletic populations, some studies have demonstrated that LV mass can be related to lean tissue mass than BSA so existence of such relation in endurance athletes can be present.

From the literature, a definite lacunae found was that a very few studies have concentrated on female data. So the present study was conducted to investigate the cardiac structure of cyclists and runners of both the genders and compare it with a normal sedentary population taking in account the cardiac structure measurements done by transthoracic echocardiography; and to study whether any association between body composition measurements and cardiac morphology exists.

MATERIALS AND METHODS

28 cyclists (Females=6, Males=22) and 26 runners (Females=10, Males=16) were studied and compared with a control group of 38 individuals (Females=20, Males=18) all aged between 18-25 years of age. Males and females both were included in the study so as to compare the results between the two gender groups. The cyclists and runners were involved in their respective sport for a minimum of 5 years and control group were sedentary population not involved in any sporting activity. All the athletes were studied during periods of active training. All athletes had represented themselves at regional, national or international level. None of the subjects had any past medical history or was taking medication. All subjects denied the use of steroids. Approval for the above study was taken from institutional ethics committee.

Table: Representation of distribution of athletes according to level of participation.

Level of Participation	Athletes	
	Female (n=16)	Male(n=38)
Regional level	3	5
National level	8	15
International level	5	18

2.1 Physical examination

Routine measurements and calculations included total body weight, height; body surface area and body mass index were recorded. Body surface area (BSA) was calculated using the DuBois equation (1916).Body mass index (BMI) was calculated by the formula weight in kilograms divided by square of height.

2.2 Electrocardiography

Each subject was studied in the morning. A standard 12 lead resting electrocardiogram was recorded on an electrocardiograph at a paper speed of 25mm/s.

2.3 Echocardiography

Echocardiography was performed by the same cardiologist every time and with the subject rotated to left side, using a PHILIPS iE33 Matrix (U.S.A) machine with 2.25 Hz transducer. The transducer was placed on the chest wall where maximum amplitude of the mitral valve was recorded. Three measurements were taken for each reading and average was then calculated. At rest, the left ventricular end diastolic and end systolic diameters, interventricular septum and left posterior wall thicknesses were measured from the parasternal long and short-axis view, just below the mitral valve level according to the recommendations of the American Society of Echocardiography (Devereux et al, 1977; Sahn J et al, 1978). Left ventricular mass (LVM,gram) was calculated from the formula (Douglas PS et al 1987). $LVM=0.8\{1.04[(\{LVEDD+IVS+PWT]^3 - LVEDD^3)]\}+0.6$. (LVEDD= Left ventricular end diastolic diameter (mm), PWT= posterior wall thickness (mm), IVS= Interventricular septal thickness (mm) in diastole. LVM index (g/m^2) was also calculated taking height and weight of the participants in consideration. Relative wall thickness (RWT) was calculated as twice diastolic posterior thickness divided by diastolic cavity diameter[23-25]. RWT was defined enlarged and labelled concentric remodelling if RWT >0.45. The RWT was considered reduced and defined eccentric remodelling if RWT >0.42.

2.4 Hydrostatic Underwater Weighing

Body fat % was also calculated for all the subjects by hydrostatic underwater weighing machine. Fat weight and lean tissue mass of all the participants was also calculated.

Then the data was statistically analyzed by SPSS software and mean standard deviation were calculated. One way ANOVA was then applied to the study data.

RESULTS

Anthropometric characteristics of the subjects are represented in Table 1. The subjects varied for weight significantly and the athletes were heavier than the control group. Body surface area and body mass index also differed significantly in between the groups showing more values for the athletes. Resting heart rate were lower in athletes than in the control group ($p<0.05$) but did not differ between the two groups of athletes.

Table 1: Kinanthropometric variables of the participants.

Variable	Runners		Cyclists		Control	
	Female(n=6)	Male(n=22)	Female(n=10)	Male (n=16)	Female(n=20)	Male(n=18)
Age (years)	19.50±0.83	19.27±1.69	20.90±1.96	20.87±1.36	21.70±1.21	21.72±1.84
Height (cm)	159.00±5.35	170.72±5.52	158.80±6.84	173.31±4.74	158.80±6.40	167.77±7.47
Weight (kg)	45.83±6.36	56.59±7.58	52.00±4.87	62.87±7.71	58.80±8.50	66.11±9.02
Body surface area (m^2)	1.43±0.10	1.65±0.09	1.51±0.09	1.75±0.11	1.59±0.11	1.75±0.13
Body mass index (kg/m^2)	18.11±2.37	19.55±3.14	20.67±2.09	20.90±2.08	23.40±3.91	23.87±2.99

Table 2: Echocardiographic measurements of the subjects.

Variable	Runners		Cyclists		Control	
	Female	Male	Female	Male	Female	Male
LVEDD	49.51±3.80	54.10±3.29	54.20±3.79	56.31±1.31	42.35±2.86	43.88±2.82
LVESD	32.66±3.44	31.00±3.65	32.83±3.31	33.20±3.11	27.22±2.13	28.16±2.40
IVS	9.76±1.79	10.41±1.35	9.09±0.98	10.23±0.97	7.90± 1.29	8.27±1.01
PWT	7.66±0.81	8.81±1.00	8.30±0.82	9.41±0.71	7.05± 0.94	7.27±0.89
LVED vol	91.21±22.28	129.66±25.82	107.86±16.75	152.18±24.32	90.75±20.80	103.62±22.85
LVES vol	45.01±14.61	67.84±18.10	51.57±8.53	70.11±17.91	39.65±13.38	53.66±14.90
LV mass	146.66±10.23	198.36±30.10	189.10±33.79	214.75±16.18	94.90±20.01	105.33±20.99
LV mass index	104.16±13.52	118.20±11.43	120.77±14.92	123.50±7.72	57.43±13.85	59.50±10.21
RWT	0.31±0.05	0.32±0.04	0.29±0.03	0.33±0.02	0.33± 0.04	0.33±0.04
FS%	34.15±2.74	38.95±5.28	38.35±3.19	37.86±3.79	35.51±3.94	34.75±5.11
EF%	71.33±5.20	67.16±7.37	66.70±5.55	68.31±6.57	64.60±3.40	64.37±5.18
RVD	19.63±2.31	24.45±6.07	22.83±2.05	24.50±2.94	21.75±3.27	22.91±3.03
RVT	6.65±1.22	7.75±2.01	7.76±2.08	7.50±1.63	6.65± 1.22	6.63±0.63
AR diameter	26.41±1.85	27.77±2.51	26.25±2.27	28.93±2.48	23.50±1.27	23.79±0.86

Table 3: Hydrostatic underwater weighing measurements of the subjects

Variable	Runners		Cyclists		Control	
	Females	Males	Females	Males	Females	Males
%Body Fat	29.50±7.53	29.29±5.68	32.62±4.04	26.30±6.72	28.81±5.75	26.52±5.08
Fat weight (kg)	16.93±11.09	16.82±4.87	17.05±3.15	17.57±4.72	19.02±4.74	16.89±4.42
Lean tissue mass (kg)	36.89±10.04	38.45±10.06	39.96±4.78	49.14±10.32	45.41±4.45	44.81±5.11

Echocardiographic data

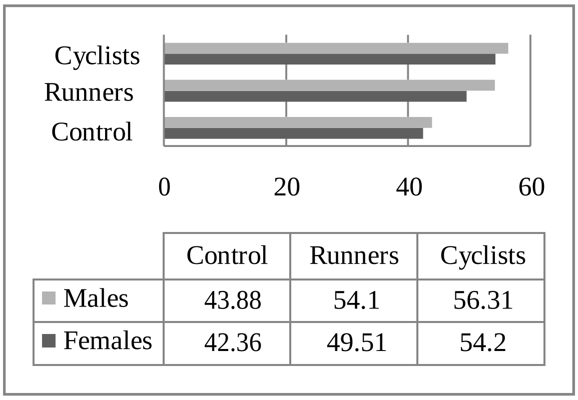

Figure 1. Showing LV end diastolic dimension in all subjects.

3.1 Left ventricular internal dimensions

There was a significant difference between the three groups of athletes and controls with respect to left ventricular end- diastolic and end systolic dimension.

3.2 Interventricular septum thickness

There was significant with respect to interventricular septum thickness between control subjects and the athletes but not among cyclists and runners.

3.3 Posterior wall thickness

There was a significant difference in the posterior wall thickness between the athletes and the control subjects and also between the cyclists and runners. Cyclists showed higher values for posterior wall thickness than runners.

3.4 Left ventricular mass

The mean left ventricular mass of the controls was significantly less than the cyclists and runners. Left ventricular mass index was calculated which was also significant for the cyclists and runners than controls.

3.5 Left ventricular volume

The left ventricular end diastolic and end systolic volume was measured in diastolic and systolic phase respectively. The male athletes showed significant difference from female athletes. Significant difference was seen in between athletes and controls.

3.6 Ejection fraction and fraction shortening percentage

Ejection fraction percentage was found to be highest among female runners with significant difference with the controls and males. Fraction shortening percentage was found to be statistically insignificant.

3.7 Right ventricular dimensions

Right ventricular measurements of internal dimension and thickness were taken by M-mode echocardiography. Males showed significant differences between controls and athletes while female data was insignificant.

3.8 Aortic root diameter

Aortic root diameter was found significantly higher in cyclist and runners than the control groups.

3.9 Mean relative wall thickness

No significant difference was found between the relative wall thicknesses between all the groups.

3.1.1 Hydrostatic underwater weighing

Table 3 shows body fat %, fat weight and lean tissue mass calculated for all the groups. Body fat % was found to be significant for the males but not for females when compared to the control group. Fat weight found to be statistically significant for both males but not for females and lean tissue mass was found to be significant for both males and females.

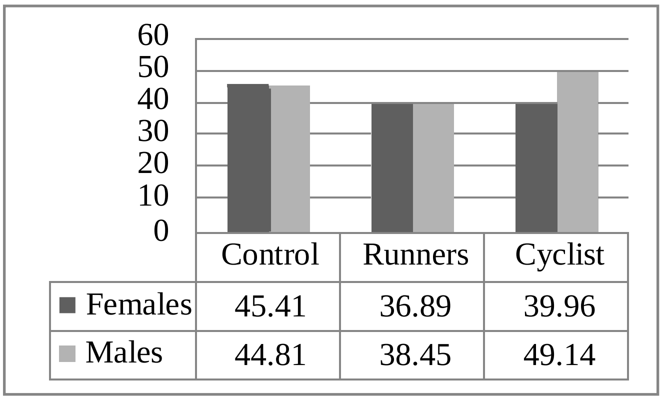

Figure 2. Showing distribution of Lean Tissue Mass in the subjects.

DISCUSSION

Eccentric left ventricular hypertrophy is characterized by an increase in the internal diameter of the left ventricle with a proportionate increase in wall thickness; this is attributed to volume overload. Concentric hypertrophy does not produce changes in the internal diameter, but left ventricular wall thickness is increased as a result of pressure overload.

The runners clearly develop eccentric hypertrophy as evidenced by the increased left ventricular cavity dilatation with the repeated volume overloading of predominantly isotonic endurance training. The cyclist's heart, however, showed an increased internal diameter but a disproportionate increase in posterior wall thickness. This mixed type of eccentric-concentric hypertrophy may be the result of both volume and pressure overload on the cyclist‘s heart as a result of a combination of mainly isotonic exercise with isometric work of the arms and the upper part of the body in their training protocol.

Left ventricular dimensions have been extensively evaluated in athletes. The meta analysis done and concluded that there is left ventricular enlargement and changes in mass resulting from systematic training in different sports disciplines. As the dimension increases the volume of the left ventricular chamber also increases to pump more blood during the increased demands of the exercise period.

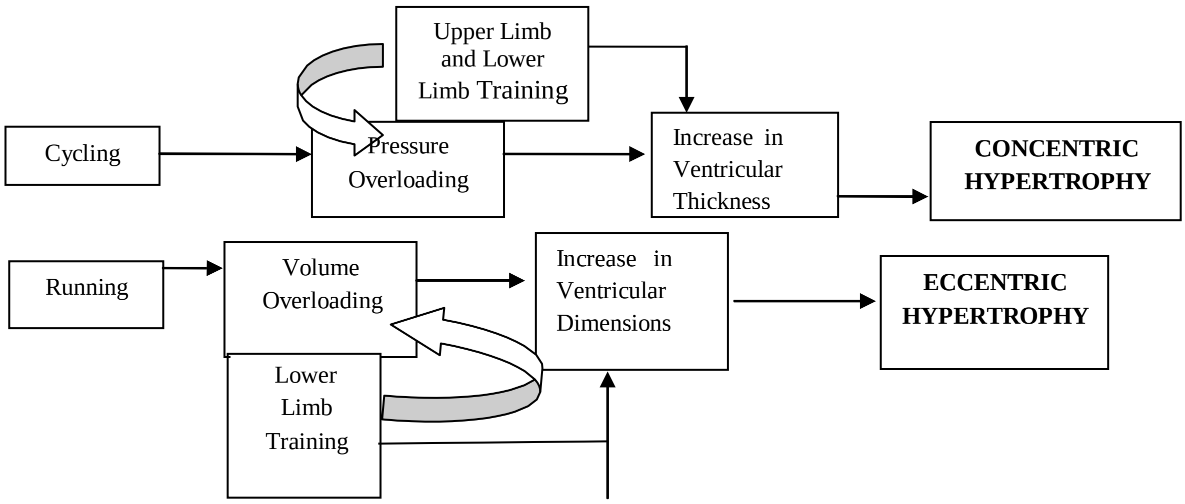

Figure 3: Representing the effect of training on cardiac morphology.

The increase in left ventricular mass correlates with increase in left ventricular dimensions and thickness. Increased myocardial mass has been found to be due to both cavity dilatation and thickness in endurance athletes.

The effects of exercise events on right ventricle have been reported [18,19]. We detected larger right ventricular dimensions in athletic males than controls. It shows that cardiac remodelling is not confined to the left ventricle only. Scharhag et al. (2002) compared 21 male endurance athletes and controls by magnetic resonance imaging; and concluded that right ventricular end diastolic volume was increased by 25% and its mass by 37%. Some previous studies have demonstrated that endurance athletes tend to have larger right ventricle cavity and thicker free walls [20, 21]. From our study we can conclude that right ventricle enlargement parallels left ventricle enlargement but gender differences were seen.

The aorta also experiences a significant hemodynamic load during training and exercise. The nature of this load is dependent on sports type, endurance training causing high volume aortic flow with modest systemic hypertension and strength activity resulting in normal volume aortic flow with potentially profound systemic hypertension. Our results have showed aortic dilatation in both the genders of the athletic group when compared to sedentary group. It can be concluded that exercise training can result in aortic remodelling in adjunct to ventricular remodelling in athletes. Some studies [22-28] has showed similar results in the past. Pellicia et al. (2010) have reported aortic root dimensions in a group of 2317 athletes and have found that the largest measurements are seen in endurance athletes like runners and cyclists.

The relative wall thickness and fractional shortening showed no significant results in our study.

The body fat % and fat weight were found to be higher in male athletes as compared to controls and females showed no significant differences. Cycling and running, both being high endurance sports involving large muscle groups and isotonic and isometric sports training showed high lean tissue mass as compared to sedentary group. Lean tissue mass was found to be correlating to the left ventricular mass (r^2=0.04) in females and to left ventricular mass (r^2=0.01) and thickness (r^2=0.01) in males thus it was found to be a determinant of LV mass in endurance athletes. Suggesting that greater the lean tissue mass in trained athletes; greater is the LV mass. Thus by controlling the lean tissue mass, a physical component which can be controlled by various modes of training; we can influence the LV morphology in an individual.

CONCLUSION

The results showed that regular participation in sports induces cardiac hypertrophy or the athlete‘s heart and athletic training has a causal role in the development of sports specific profiles of cardiac structure. The increase of ventricular wall thickness in relation to the ventricular dimension appears to be proportionate in runners; it is disproportionate in cyclists, probably because of the isometric training component during cycling. Hence runners show eccentric hypertrophy and cyclist showed mixed eccentric and concentric hypertrophy.

This study suggests that the LV dilation and LV hypertrophy seen in endurance-trained athletes may reflect a normal physiologic response to increased lean tissue mass and highlights the importance of accurate assessment of lean tissue mass in athletes to fully evaluate the effects of endurance training on cardiac morphology.

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