International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

MRI Study for Comparative Measurement of Cardiac Parameters between Endurance and Resistance Athletes

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Abstract: ***Background**: Long lasting physical training has an influence on the geometric and functional characteristics of the heart. Long - term high dynamic activity resulted in a massive increase in both the internal diameter and wall thickness of left ventricle (eccentric hypertrophy). On the other hand, athletes involved in sports characterized by intense isomeric exercises have an increased LV wall thickness without a change in the chamber size (concentric hypertrophy). **Aim**: The primary objective is to compare the measurement of left ventricular wall thickness (LVWT) between endurance and resistance athletes. The secondary objectives are to compare the measurements of left ventricular mass (LVM), Left ventricular end - diastolic volume (LVEDV), left ventricular end - systolic volume (LVESV) and stroke volume (SV) between endurance and resistance athletes. **Settings and designs**: The present study was conducted in the Department of Radio diagnosis, of a tertiary care hospital. All cases underwent MRI brain with 1.5 Tesla MRI. **Materials and methods**: The study included total 30 cases, 15 each of endurance and resistance athletes, at the tertiary care institute. After obtaining the complete set of images, the morphological and functional variables of cardiac chambers were measured. **Statistical analysis**: T - tests for independent samples were used to compare the average values between these groups. **Conclusion**: The endurance athletes had significantly higher LVWT, LVM, LVEDV and LVESV than resistance athletes. SV values were increased in resistance athletes.*

Keywords: MRI, LVWT, LVM, LVEDV, LVESV, SV

1. Introduction

The Athlete's heart (AH) has been extensively described in male athletes by George et al [1]. Long lasting physical training has an influence on the geometric and functional characteristics of the heart [2, 3]. Because of the specific exercise, the adaptive response of the cardiovascular system may differ for the various kinds of sports activity. A cornerstone of this phenomenon has been the concept that cardiac structural adaptation follows a dichotomous course of eccentric hypertrophy (balanced increase in chamber and wall dimensions) with endurance training versus concentric hypertrophy (disproportionate increase in wall thickness) with resistance training [4, 5]. Previous studies have shown strong support for the model of divergent cardiac adaptation, first discusses by Morganroth et al [6, 7, 8]. It is hypothesized that these adaptations reflect differential hemodynamic loading during acute training by Grossman et al [9]. They asserted that long - term high dynamic activity (running, swimming, etc.) resulted in a massive increase in both the internal diameter and wall thickness of left ventricle (eccentric hypertrophy). On the other hand, athletes involved in sports characterized by intense static or isomeric exercises appear to have an increased LV wall thickness without a change in the chamber size (concentric hypertrophy).

Despite this pervasive knowledge, contradictory evidence exists. Pluim et al have recently published the results of meta - analysis in which they compared the morphological forms of heart response in endurance, power and combined (endurance and power) sports [10]. They concluded that though slight difference might exist in cardiac adaptation, such differences were smaller than expected. They also found cases where morphological adaptation presented no relation with Morganroth's theory. It is more difficult to prove the presence of divergent cardiologic adaptation in the case of combined dynamic and static sports (combat sports, rowing, kayak, canoeing, gymnastics, etc.) where the heart is exposed to volume overload, high cardiac output and pressure overload. Allied to this on - going controversy, a specific technical issues warrant evaluation. Only echocardiographic AH studies were included in many of the previous meta - analysis [11, 12, 13]. Cardiac magnetic resonance imaging (CMR) has now become the gold standard tool for cardiac structural assessment. Clinically significant differences between echocardiography and CMR have been reported by Bellenger et al [14]. Developments in CMR have also resulted in novel regional functional indices as well as greater access to morphological and functional data of the ventricular chambers.

So far, no full agreement of the opinions about causes and condition of divergent cardiologic adaptations has been reached. Most of the mentioned morphological and functional measurements of the LV were made by echocardiography [15]. In contrast with the high number of echocardiographic data, relatively few findings based in MRI measurements have been published so far, and even these studies referred only to some isolated branches of sports [16].

This study compares the morphological and functional data of the left ventricle, gained by MRI from athletes engaged in endurance and power activities, to find adaptation specifics caused by the different load characteristics.

2. Method

The present study was conducted in the Department of Radio diagnosis, of an urban tertiary care teaching hospital. The study included total thirty (30) cases, fifteen (15) each of endurance and resistance athletes, at this tertiary care institute during 2017 - 2020. Relevant clinical and imaging details viz. height, weight and details of MRI were noted in respect of all the cases. Inclusion criteria included Endurance and resistance athletes (>10 hrs of trg/day for > 6 months) with age 18 - 39 years. Exclusion criteria included cases not willing to undergo MRI, associated history of trauma or CAD, cases with additional pathology detected on echocardiography or electrocardiography. All cases underwent MRI brain with 1.5 Tesla MRI scanner (Magnetom Symphony: Siemens; Germany). The various sequences and the parameters used are as follows:

a) Images were taken in the short - axis plane of the heart, derived from coronal and sagittal scout views, using double oblique angulations.
b) Cine MRI was performed by using a gradient echo sequence (flip angle 40 deg, TE 6.8 ms, TR - 60 ms).
c) Ten slices were obtained (thickness 8 mm, interslice gap 0 mm)
d) FOV – 450 mm2 and acquisition matrix was interpolated to 256 x 256 for display purposes.
e) No contrast was administered during the study.

After obtaining the complete set of images, the following morphological and functional variables were measured:

- Left ventricular wall thickness (LVWT)
- Left ventricular mass (LVM)
- Left ventricular end - diastolic volume (LVEDV)
- Left ventricular end - systolic volume (LVESV)
- Stroke volume (SV)

The measurement of the left ventricular (LV) wall volume in all slices with known wall thickness (8 mm) was the first step to determine LVM. To collect left ventricular wall volume data the endocardial and epicardial contours of the left ventricle were drawn in each transverse slice and in each cardiac phase. The largest (LVEDV) and the smallest (LVESV) LV volume represent the diastolic and the systolic cardiac phase, respectively. The left ventricular wall volume was obtained after the subtraction of LVEDV from the diastolic heart volume (volume based on epicardial contours). LVM was then calculated by multiplying the total LV wall volume by the specific gravity of cardiac muscle (1.05 gm/ml).

Left ventricular wall thickness (LVWT) was measured on each slice. The chord between the endocardial and epicardial contours represents wall thickness.

Left ventricular volumes (LVEDV, LVESV) were obtained by summing the end - diastolic and end - systolic cross - sectional endocardial areas, respectively. These values were multiplied by the sum of the slice thickness, so both end - diastolic and end - systolic volumes could be calculated. The image that displayed the smallest size of the cavity was regarded as the end - systolic image, and that of displaying the largest size of the cavity was regarded as the end - diastolic image.

Stroke volume (SV) was determined by subtracting end - systolic volume from the end - diastolic volume.

Statistics

T - tests for independent samples were used to compare the average values of the MRI data between the study groups. All results are reported as mean values followed by the standard deviation. P value < 0.05 was considered significant.

3. Results

The height, weight & body surface area of the endurance and resistance athletes are given in table 1 and table 2 respectively. There was no significant difference in the anthropometric characteristics of the three groups. The LVWT, LVM, LVEDV, LVESV and SV for both the endurance and resistance athletes are summarized in table 3 and table 4. In the present study, the endurance athletes had significantly higher LVWT than resistance athletes ($p < 0.05$) (Table 5). The LVM values also show a significant difference between the endurance and combined athletes (Table 6). Endurance athletes had significantly greater LVEDV and LVESV than resistance athletes ($p < 0.05$) (Table 7, 8). SV values were increased in resistance athletes, as compared to the endurance athletes ($p < 0.05$) (Table 9).

4. Discussion

The study compared the morphological and functional data of the left ventricle, gained by MRI from athletes engaged in endurance and resistance athletes, to find adaptation specifics caused by the different load characteristics. Our results are in a good agreement with the values measured by other authors in young male subjects [17, 18]. LV mass values of the trained groups were somewhat less than reported by others [19]; this can be explained by the fact that our athletes were not top - level but second - class competitors and the smaller sample size as compare to other studies.

Both athlete groups had larger LV wall, chamber dimensions and mass which supports the existence of a morphological AH, as done in the study by Pluim et al [10]. The endurance - trained athletes had marginally larger LV mass and significantly greater LVEDD and LVEDV than resistance athletes, supporting the contention that endurance athletes tend to present with the largest LV dimensions. Furthermore, the pattern of LV morphology in the endurance - trained athletes, a bigger LV chamber and proportionately larger LV walls, is commensurate with an eccentric LV hypertrophy. Resistance athletes had a marginally higher SV than endurance athletes. A smaller sample size for the resistance athletes would have resulted into this. Although controversial, individual studies have reported an improved diastolic filling at rest in athletes by Pluim et al. Yet this has often been dependent upon the specific parameter assessed by George et al [11]. The potential importance of enhanced diastolic function in the development of maximal SV as well as putative mechanisms (preload or intrinsic relaxation properties), requires further evaluation. This supports a balanced cardiac hypertrophy that is assumed to be wholly physiological in nature. Whilst there are noticeable fewer resistance - training studies in the existing literature, the current data confirm the observation that resistance athletes display some morphological characteristics of the AH.

LVWT was bigger in endurance athletes than resistance athletes. Pluim et al noted some support for concentric hypertrophy in resistance athletes due to an increased wall to chamber ratio. As opposed to dichotomous cardiac structural responses to endurance and resistance - training, it could be argued that both athlete groups present with a similar qualitative cardiac adaptation on a continuum, with greater cardiac dimensions in endurance athletes reflecting a greater overall training volume. The lack of concentric - type hypertrophy in resistance athletes could be due to; (a) a limited exposure time to an elevated hemodynamic afterload as an increase in blood pressure only occurs sporadically during resistance training because of the intermittent nature of repetitions, sets and work - to - rest ratios. The exposure to an elevated hemodynamic load during exercise is likely much more consistent and substantial during endurance training; (b) the absence of any real afterload stimulus when resistance training is performed with a valsalva maneuver.

CMR is the gold standard tool for morphological assessment of cardiac chambers and mass due to its greater spatial resolution and 3 - D data provision. Recent, direct comparisons between echocardiography and MRI - derived measures of left ventricular (LV) mass and volume in athletes suggest that large absolute differences exist between these measurement modalities. Measurement variability is also substantially greater with echocardiography as described by Bellenger et al. [14]. In this study the use of CMR resulted in a higher LVEDV than echocardiography and this agrees with previous comparative studies. The difference is likely due to the biplane Simpson's technique that uses estimation and geometric modeling allied to poorer lateral resolution that makes clear delineation of the endocardium difficult. Conversely, LV mass, was greater in echocardiography in comparison to MRI. Nevertheless methodological differences should be the subject of further specific studies. In most of the morphological parameters (LVWT, LVM, LVEDV, LVESV and SV) the endurance athletes showed higher values than the resistance athletes. These findings coincide with other published data [15]. Earlier studies comparing adaptation characteristics of the heart between endurance - and power - athletes reported divergent cardiac adaptation according to load specifics (eccentric - , concentric - hypertrophy) [16]. This theory can be taken into consideration in the case of sports where isometric and isotonic training exercises are frequently performed during the training and heart is exposed to both volume or pressure overload. According to the present study, a remarkable divergence in cardiac adaptation can be observed between endurance and resistance athlete groups. The current findings also provide relevant information for those interested in the nature of the upper limits of human cardiac, physiological adaptation to training. This knowledge will inform cardiac screening and the differential diagnosis of AH from pathological adaptation. It is also important to highlight that wall thicknesses and the LV end diastolic dimension, although increased, do not fall within the pathological range seen in hypertrophic or dilated cardiomyopathy in either resistance or endurance trained athletes. This knowledge will further aid the diagnostic challenges associated with pre - participation screening of the competitive athlete. Consequently, this meta - analysis provides a useful re-evaluation of concepts and models in the AH literature.

5. Data Availability

The datasets analyzed are available from the corresponding author on request.

6. Consent

The patients signed consent forms are available from the author on request.

7. Funding

No funding is required

8. Conflicts of Interest

No conflict of interest has been declared.

9. References

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Table 1: Endurance athletes

Height	Weight	Body surface area
170	72	1.84
175	76	1.92
171	70	1.82
170	69	1.81
168	67	1.77
176	70	1.85
165	62	1.69
168	63	1.71
175	65	1.78
172	63	1.73
174	65	1.77
173	74	1.89
174	72	1.87
178	74	1.91
180	77	1.96

The mean values ± SD are as follows:
1) Height: 172.6 ± 3.895
2) Body weight: 69.26 ± 4.753
3) Body surface area: 1.82 ± 0.077

Table 2: Resistance athletes

Height	Weight	Body surface area
170	73	1.86
168	62	1.7
172	60	1.69
174	72	1.87
175	71	1.86
177	76	1.93
170	70	1.82
171	70	1.82
174	71	1.85
168	66	1.75
165	62	1.69
170	68	1.79
172	70	1.83
173	71	1.85
168	67	1.77

The mean values ± SD are as follows:
1) Height: 171.13 ± 3.073
2) Body weight: 68.6 ± 4.317
3) Body surface area: 1.805 ± 0.0697

MRI measurements

The LVWT, LVM, LVEDV, LVESV & SV of the endurance and resistance athletes are given in table 3 and table 4 respectively.

Table 3: Cardiac parameters in endurance athletes

Sr. No.	LVWT (mm)	LVM (gm)	LVEDV (ml)	LVESV (ml)	SV (ml)
1	10.29	186.9	136.3	55.61	80.69
2	10.3	187.8	136.3	56.1	80.2
3	10.35	183.4	135	55.4	79.6
4	10.28	184.1	136	55.9	80.1
5	10.25	182.9	136.91	55.91	81
6	10.3	188.4	135.68	54.38	81.3
7	10.31	188.1	134.95	55.28	79.67
8	10.29	181.0	135.44	55.64	79.8
9	10.28	187.2	135.73	55.63	80.1
10	10.35	186.9	136.37	55.67	80.7
11	10.29	188.1	135.08	55.63	79.45
12	10.27	187.2	135.28	55.48	79.8
13	10.32	187.6	135.14	55.29	79.85
14	10.3	188.9	135.7	55.6	80.1
15	10.29	188.8	136.63	55.63	81

The mean values ± SD are as follows:
1) LVWT: 10.29 ± 0.025 mm.
2) LVM: 186.486 ± 2.428 gm.
3) LVEDV: 135.76 ± 0.627 ml.
4) LVESV: 55.543 ± 0.390 ml.
5) SV: 80.224 ±0.576 ml.

Table 4: Cardiac parameters in resistance athletes

Sr. No.	LVWT (mm)	LVM (gm)	LVEDV (ml)	LVESV (ml)	SV (ml)
1	9.39	166.2	131	49.74	81.26
2	9.4	166.8	130.35	48.9	81.45
3	9.3	164.9	130.26	48.96	81.3
4	9.45	172.3	130.3	49.1	81.2
5	9.42	170.2	131.1	49.4	81.7
6	9.27	169.1	130.52	49.3	81.22
7	9.4	172.1	130.21	48.9	81.31
8	9.41	172.1	130.8	49.5	81.3
9	9.35	165.3	131	49.64	81.36
10	9.28	163.6	131.07	49.7	81.37
11	9.3	163.7	131.06	49.8	81.26
12	9.39	171.7	129.87	48.6	81.27
13	9.4	171.1	130.92	49.72	81.2
14	9.38	170.2	130.43	49.13	81.3
15	9.46	171.8	130.64	49.4	81.24

The mean values ± SD are as follows:
1) LVWT: 9.37 ± 0.056 mm.
2) LVM: 168.5 ± 3.608 gm.
3) LVEDV: 130.635 ± 0.388 ml.
4) LVESV: 49.319 ± 0.372 ml.
5) SV: 81.316 ± 0.125 ml.

Table 5: Comparison between mean of LVWT between endurance and resistance athletes

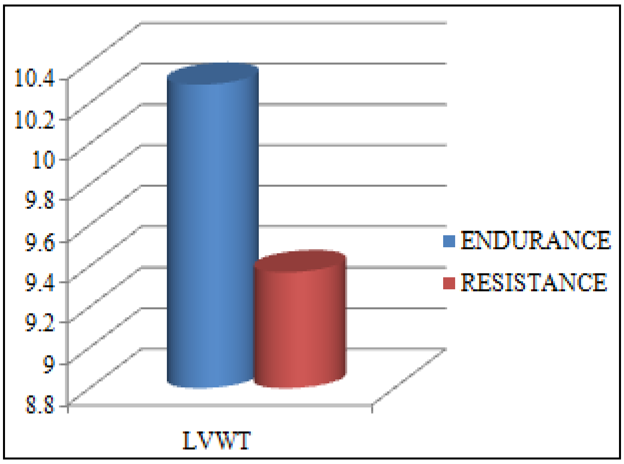
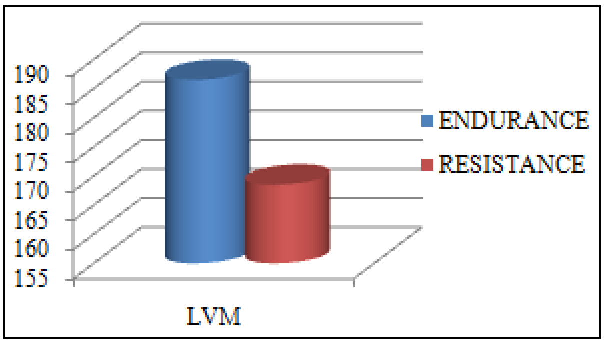
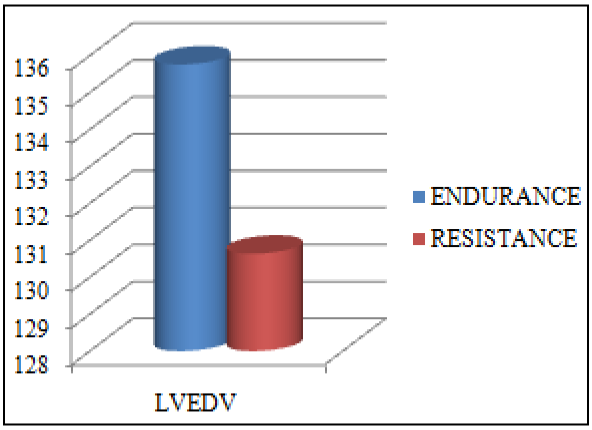


Table 6: Comparison between mean of LVM between endurance and resistance athletes



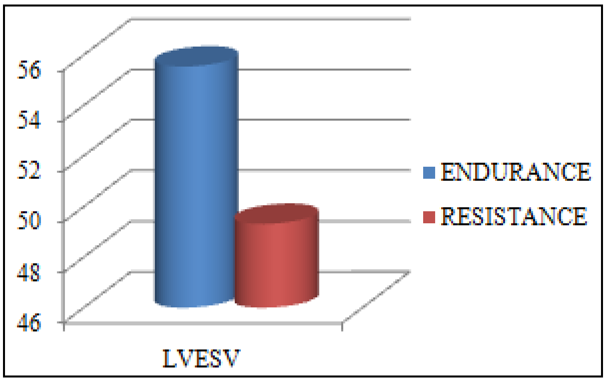
Endurance athletes had significantly greater LVM values than resistance athletes ($p < 0.05$).

Table 7: Comparison between mean of LVEDV between endurance and resistance athletes



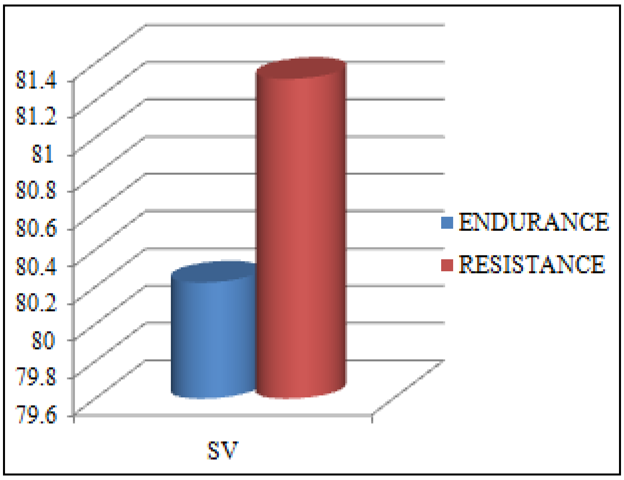
Endurance athletes had significantly greater LVEDV than resistance athletes ($p < 0.05$).

Table 8: Comparison between mean of LVESV between endurance and resistance athletes



Endurance athletes had significantly greater LVESV than resistance athletes ($p < 0.05$).

Table 9: Comparison between mean of SV between endurance and resistance athletes



SV values were found higher in resistance athletes than endurance athletes and they were significant ($p < 0.05$).