Physiologic Limits of Cardiac Remodelling in Asian Competitive Athletes – A Single Centre Study

Dear Editor,

An athlete's heart describes a conglomeration of structural, functional and electrical adaptation in the heart of an athlete. Exercise-induced cardiac remodelling (EICR) varies between ethnicities, gender and type of sports.[1-6] This has been well studied in non-Asian athletes. However, to date, none has been published for South East Asian (SEA) athletes. Our study aimed to demonstrate the presence of EICR in elite SEA athletes for the first time.

Materials and Methods

This is a single centre cross-sectional case-control study performed in 2004 at Changi General Hospital, a tertiary hospital in Singapore. All athletes were recruited from Changi Sports Medicine Centre. The control group was age-, gender- and race-matched healthy sedentary adults. Athletes were defined as individuals actively training in strength or endurance sports, more than 3 times a week and exceeding 40 minutes per session for at least 5 years. Endurance athletes were also required to have a resting heart rate of less than 50 beats per minute (bpm) and have competed at a national level or above for more than 2 years. The athletes were further subclassified based on their training into endurance, resistance and mixed athletes. Triathletes were classified as mixed athletes due to their exposure to both resistance and endurance training as well as prior studies demonstrating both concentric and eccentric cardiac remodelling.[7-9] Exclusion criteria included age <21 years old, limited echocardiographic windows, hypertension, significant cardiac history or cardiac surgery. The study was approved by the institutional review committee.

Study Design

All subjects received a clinical assessment, a resting electrocardiogram (ECG) and a targeted echocardiogram.

The echocardiogram consisted of routine basic 2D and spectral Doppler echocardiographic parameters, as well as tissue Doppler imaging (TDI), acquired by experienced sonographers using GE Vivid 7 and interpreted by 2 trained echocardiologists. All chamber quantifications were measured according to the American Society of Echocardiography Chamber Quantification Guideline.[10]

Statistical Analysis

The non-parametric echocardiographic data was mainly analysed using Mann-Whitney test with a probability value <0.05 considered statistically significant. A chi-squared test of independence was used to assess the relationship between the different types of athletic training and left ventricular (LV) geometry. All statistical analysis was performed using SPSS version 22 (IBM Corp, New York, USA).

Results

Thirty-three athletes and 17 control subjects—of Asian descent—were recruited (n = 50). One athlete was noted to have an atrial septal defect and was excluded from the study.

Baseline Characteristics

There were more males amongst the athletes as compared with the controls (88% vs 65%, P = 0.024). Otherwise, there were no significant differences in the height, weight, body mass index, body surface area, resting heart rate and blood pressure between the 2 groups (Table 1). Most of the athletes participated in mixed or endurance sports (Table 2), with the remaining being resistance athletes (4/33, 12.1%). The athletes underwent an average of 6.5 ± 3.6 hours per week of intense training while the control subjects had no routine exercise exposure.

Table 1. Baseline Characteristics of Study Participants

	Control	Athletes	*P* Value
Gender			
Male	11/17 (65%)	29/33 (88%)	0.024
Age	28.8 ± 4.6	36.4 ± 4.7	0.07
Height (m)	1.66 ± 0.08	1.69 ± 0.08	0.284
Weight (kg)	60.4 ± 11.7	65.2 ± 12.4	0.234
Body surface area (m^2)	1.6 ± 0.24	1.7 ± 0.2	0.147
Body mass index (kg/m^2)	21.7 ± 3.0	22.6 ± 3.0	0.424
Resting blood pressure			
Systolic (mmHg)	119.3 ± 14.8	120.3 ± 12.7	0.936
Diastolic (mmHg)	71.2 ± 9.3	70.7 ± 8.9	0.904
Resting heart rate (bpm)	63.6±8.7	66.5±10.2	0.352

Data expressed as mean ± standard deviation.

Table 2. Athletes Based on Type of Training and LV Geometry

Type of Sport	n	Normal Geometry	Concentric Remolding	Eccentric Hypertrophy	Concentric Hypertrophy	Total	*P* Value
Endurance training		8	0	2	0	10	0.930
Marathon runner	8						
Squash	1						
Sprinter	1						
Resistance training		2	1	1	0	4	
Body builder	2						
Boxer	2						
Mixed training		11	2	5	1	19	
Triathlon athletes	15						
Mountaineer	3						
Sailing	1						
						33	

LV: Left ventricular

ECG Characteristics of Athletes

None of the 33 ECGs showed any abnormalities, as defined by the latest International Criteria.[11]

Echocardiographic Results

The athletes demonstrated highly significant increases in all the 3 cardiac chambers sizes that were studied as compared to healthy controls (Table 3). They had significantly larger globally dilated LV cavities (LV end diastolic volume index [LVEDVi] 51.3 ± 8.8 mL/m^2 vs 41.1 +/- 11.1 mL/m^2, $P = 0.002$), larger left atrial (LA) sizes (LA volume index [LAVi] (mL/m^2), 34.7 ± 7.9 vs 23.4 ± 6.7, $P < 0.001$) and dilated right ventricles (RV) (RV internal diameter [RVID] (mm), 25 ± 4.8 vs 18 ± 4.0, $P < 0.001$).

Table 3. Echocardiographic Parameters of Study Participants

Parameters	Control (mean ± SD)	Athletes (mean ± SD)	*P* Value
LV end diastolic diameter (mm)	46 ± 4.5	52 ± 3.6	<0.001
LV end diastolic volume (mL)	67 ± 18.7	89.7 ± 21	<0.001
LV end diastolic volume index (mL/m^2)	41.1 +/- 11.1	51.3 ± 8.8	0.002
LA volume (mL)	37.8 ± 12.6	59.7 ± 14.8	<0.001
LA volume index (mL/m^2)	23.4 ± 6.7	34.7 ± 7.9	<0.001
RV internal diameter (mm)	18 ± 4.0	25 ± 4.8	<0.001
LV mass (g)	110.5 ± 35.2	149.1 ± 35.1	0.001
LV mass index (g/m^2)	67.7 ± 17.0	85.2 ± 18.0	0.002
LV wall thickness (mm)	7 ± 1.2	8 ± 1.2	0.025
LV ejection fraction (%)	66.5 ± 6.5	63.4 ± 7.3	0.246
E/A ratio	1.9 ± 0.5	2.08 ± 0.65	0.139
Septal E’	0.12 ± 0.02	0.11 ± 0.02	0.067
E/E’ ratio	7.0 ± 1.2	7.4 ± 1.8	0.363
Deceleration time (DT)	182.5 ± 40.6	168.3 ± 43.8	0.153
Relative wall thickness (RWT)	0.30 ± 0.06	0.28 ± 0.05	0.952
Isovolumetric relaxation time (IVRT)	87.3 ± 13.3	93.0 ± 16.4	0.084

LA: Left atrial; LV: Left ventricular; RV: Right ventricle; SD: Standard deviation

Compared to the control group, there was also significantly increased LV mass (LV mass index 67.7 ± 17.0 vs 85.2 ± 18.0 g/m², $P < 0.002$), and LV wall thickness (7 ± 1.2 vs 8 ± 1.2 mm, $P < 0.025$) in the athletes. The maximum septal thickness observed was 12 mm in a male marathoner. The maximum LV internal diameter measured at LVIDed was 5.7 cm. There was no significant difference in LV ejection fraction (LVEF) between the 2 groups ($P = 0.26$).

Morphologically, 20% (2/10) of endurance athletes and 26.3% (5/19) of mixed athletes demonstrated LV eccentric remodelling. There was no significant difference in the incidence of LV-eccentric remodelling between endurance, resistance and mixed athletes ($P = 0.93$). Of our 4 resistance athletes, 1 boxer (25%) demonstrated LV concentric remodelling (Table 2).

There was no significant differences between athletes and controls in the indices of diastolic filling (septal E’, E/A, E/E’, DT, PVa – MVa duration and IVRT) except for colour M-mode propagation velocity. Interestingly, colour M-mode propagation velocity was significantly slower in athletes (56 vs 69cm/s, $P = 0.001$).

Discussion

Our study demonstrated for the first time that the SEA athlete’s heart undergoes similar EICR as non-Asians, with all 3 cardiac chambers equally affected by exercise, confirming that the athlete’s heart is a balanced heart. We also demonstrated that the upper physiologic limit of septal thickness is only 12 mm in our SEA elite athletes. This is in contrast to elite Italian athletes whereby 1.7% exceeds 13 mm with maximum thickness of 16 mm.[12] Pelliccia et al also showed that 14% of the Italian athletes had dilated LV with LV internal diameter at LVIDed exceeding 6 cm, whereas in our athletes, the maximum LVID measured was only 5.7 cm with none exceeding 6 mm. Importantly, despite the dilated LV cavities and hypertrophy, our athletes consistently showed normal LV systolic function and diastolic function.[13]

We did not observe a significant difference in LV geometry between the athletes who underwent endurance, resistance and mixed training. The incidence of LV-eccentric hypertrophy in our endurance athletes (20%) and mixed athletes (26.3%) was lower in comparison to a similar study by Hoogsteen J et al in the Netherlands (65%).[9] The majority of athletes in our study (21/33, 63.6%) had normal LV geometry. It might appear that SEA athlete's heart remodels to a lesser extent than non-Asians. However, this could be because of the smaller Asian frame and the dimensions are measured in absolute numbers. This would imply less of a conundrum in differentiating an athlete's heart from cardiomyopathies in the grey zone for SEA athletes.

An athlete's heart is known to have normal or supernormal diastolic function. In all the diastolic indices, only the colour M-mode propagation velocity in our athletes was significantly slower, which we think could be due to slower twisting rate in athletes from bradycardia, and is unlikely to be an indicator of diastolic dysfunction in athletes. Further study on LV twist and untwist in athletes would be interesting to look at.

Limitations

Our sample size is small, mostly male and our athletes are mostly of endurance athletes. Thus, the results are limited to athletes of this profile. We were also unable to comment on the temporal relationship between exercise exposure and EICR as this was a cross-sectional study. At the time of the study, 3D echocardiography and strain imaging were not available, and hence was not studied in our athletes.

Conclusion

Our study has demonstrated similar findings of global EICR to a lesser extent in a cohort of predominant male elite endurance SEA athletes, with an upper limit of 12 mm in septal thickness and 5.7 cm in LV cavity size, in comparison to non-Asian athletes.

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Yann Shan Keh, [1]*MD, MCRP*, Puay Joo Tan, [1]*RDCS*, Siang Chew Chai, [1]*MBBS, MRCP*, Benedict Tan, [2]*MBBS, MSpMed, FAMS*, Khim Leng Tong, [1]*MBBS, MRCP, FACC*

[1]Department of Cardiology, Changi General Hospital, Singapore
[2]Department of Sports Medicine, Changi General Hospital, Singapore

Address for Correspondence: Dr Tong Khim Leng, Department of Cardiology, Changi General Hospital, 2 Simei Street 3, Singapore 529889.
Email: khim_leng_tong@cgh.com.sg