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Sport disciplines and cardiac remodeling in elite university athletes competing in 2017 Taipei Summer Universiade

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Abstract

Cardiac remodeling is common in the athletes. Little data is available regarding the cardiac remodeling on the recently proposed 4 sport disciplines among the elite university athletes.

A total of 7639 athletes participated in the 2017 Taipei Summer Universiade. Cardiac evaluation via history, ECG, and echocardiography were performed in 826 athletes who signed up for Check Up Your Heart. Athletes were grouped into one of 4 sport disciplines Skill, Power, Mixed, and Endurance.

After excluding 66 participants with missing demographic data, 13 missing echocardiographic data, and 24 inadequate echocardiographic images, a total number of 723 university athletes (mean age 23 ± 3 years, 419 males) from 99 countries engaging in 25 different sporting events were analyzed. Electrocardiograms showed that Endurance group had a slower heart rate and higher percentage of left ventricular (LV) hypertrophy (39%). Echocardiograms showed there were significant differences in LV mass index ($P < .001$), LV geometry ($P < .001$), left atrial (LA) dilatation ($P = .026$), right ventricular (RV) dilatation ($P < .001$), right atrial (RA) dilatation ($P < .0001$), and tricuspid annular plane systolic excurse ($P = .006$). LV ejection fraction, LV strain, RV strain, and LV diastolic function showed no difference in 4 sport disciplines.

Eccentric LV hypertrophy was the most common type of cardiac remodeling in the university athletes participated in 2017 Taipei Summer Universiade. Adaptive changes in chamber size were more commonly seen in Endurance sport. RA dilatation was the most sensitive to hemodynamic demand, followed by RV dilatation, LA dilatation, and LV dilatation.

Abbreviations: ASE = American Society of Echocardiography, EACVI = European Association of Cardiovascular Imaging, ECG = electrocardiogram, EPAC = European Association of Preventive Cardiology, FISU = International University Sports Federation, GLS = global longitudinal strain, LA = left atrial, LAE = left atrial enlargement, LAVI = left atrial volume index, LV = left ventricular, LVH = left ventricular hypertrophy, LVMI = left ventricular mass index, NCAA = National Collegiate Athletic Association (NCAA), RA = right atrial, RAE = right atrial enlargement, RV = right ventricular, RVH = right ventricular hypertrophy, TAPSE = tricuspid annular plane systolic excursion.

Keywords: cardiac remodelling, chamber dilatation, sport disciplines, university athletes

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JA, RL, and CL are contributed equally in this work.

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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1. Introduction

Cardiac remodeling is frequently presented in elite athletes,[1,2] and increased risk of sudden cardiac death has been reported in certain sport discipline by National Collegiate Athletic Association (NCAA).[3] Currently the American Heart Association recommends a focused personal and family history, physical examination, while the European guideline recommends to include resting 12-lead electrocardiogram (ECG) as part of the pre-participation screening for all individuals regardless of sport disciplines.[4,5] The role of 2D echocardiogram is considered as additional test for individuals with increased likelihood of cardiovascular disease.[4,5]

The Summer Universiade is an international university sports and cultural event organized by the International University Sports Federation (FISU) held every 2 years in an elected city. Thousands of elite athletes around the world gathered together to participate, making it one of the largest and celebrated sports ceremony, second only to the Olympics in size and broadcast. The 2015 Gwangju Summer Universiade reported that abnormal left ventricular (LV) geometry found in 13.2% of the participants, and concentric remodeling was the most common type among young university athletes.[6] In 2018, European Association of Preventive Cardiology (EAPC) and European Association of Cardiovascular Imaging (EACVI) published a joint position statement with classification of 4 sport disciplines based on varying degrees of isometric and isotonic component in training, namely Skill, Power, Mixed, and Endurance.[7] This study aims to define the cardiac remodeling in relation to sport disciplines among elite university athletes, using the data collected from the 2017 Taipei Summer Universiade.

2. Materials and methods

This is a retrospective, cross-sectional study conducted among student athlete in the 2017 Summer Universiade. Student athletes voluntarily participated in the screening of the Check Up Your Heart program offered by the FISU. Demographic data were obtained using an athlete reported questionnaire, and participants with incomplete records and suboptimal echocardiographic images were excluded. This study was approved by Institutional Review Board of Chang Gung Memorial Hospital.

2.1. Study population

A total of 7639 student athletes participated in 2017 Summer Universiade competition, and 826 participants voluntarily underwent the Check Up Your Heart program. Participants with missing demographic data, inadequate echocardiographic images, and missing echocardiographic data are excluded. A total of 66 participants with missing demographic data, 13 with missing echocardiographic data, and 24 with inadequate echocardiographic images and were excluded from analysis (Fig. 1). A total of 723 university athletes, from 99 countries (Fig. 2), participating in 25 different sporting events were included in the final analysis (Fig. 3). The participants were divided into the 4 sport disciplines (Fig. 4).

2.2. Twelve-lead electrocardiogram

ECG was interpreted and classified as normal, borderline, and abnormal ECG findings defined by the International recommendation for electrocardiographic interpretation in athletes published in the European Heart Journal on 2017.[8] Atrial rate, P axis, PR interval, QRS duration, QT interval, QTc, R axis of the patients were recorded. In addition, arrhythmias, bundle branch block, and ST-T changes were noted. Importantly, left ventricular hypertrophy (LVH), left atrial enlargement (LAE), right ventricular hypertrophy (RVH), and right atrial enlargement (RAE) were assessed.

2.3. 2D Echocardiography

Two-dimensional echocardiography and color Doppler data were obtained and analyzed offsite according to the 2015 American Society of Echocardiography (ASE) guideline on chamber quantification, using TOMTEC Arena software.[9] Normal or reference values were taken from the 2015 ASE guideline on chamber quantification, unless otherwise specified.[9] 2D guided left ventricular (LV) linear measurements was taken from standard parasternal long axis view during end-diastole, and end-systole, and was used to compute for LV mass indexed to body surface area, relative wall thickness, and LV volume and ejection fraction using standard formulas. LV geometry was characterized as normal, concentric remodeling, concentric hypertrophy, and eccentric hypertrophy based on LV mass index and relative wall thickness. Speckle tracking was used to determine peak LV global longitudinal strain (GLS) and was reported as an absolute value. An LV GLS value of <15% was defined as abnormal.[7]

Right ventricular (RV) outflow tract dimensions were taken from standard parasternal long- and short-axis views at the level of the great vessel views. RV base was also determined using an RV focused apical 4-chamber view. RV function was measured using 2 methods, tricuspid annular plane systolic excursion (TAPSE) in RV focused apical view, and RV GLS in modified apical 4-chamber view via TOMTEC arena. An RV GLS was reported as an absolute value with <20% defined as abnormal[9]

Left atrial (LA) volume was derived from apical 4- and 2-chamber view using biplane summation of disk equation, and indexed to body surface area. Right atrial (RA) end-systolic area was determined using an RV focused apical 4-chamber view.[9]

2.4. Image quality analysis

The image quality of 2D transthoracic echocardiography was assessed in apical 4-, 2-, and 3-chamber cutting planes to inspect LV endocardial border in the 18 LV segments. Image quality was defined as good when the LV endocardium was clearly visualized in ≥17 segments, fair when 15 to 16 segments were visible, and poor/inadequate when ≤14 of segments were visible.[10]

2.5. Statistical analysis

Data encoding was performed using Microsoft Excel, and after ensuring completeness and accuracy, the datasets was analyzed using SPSS version 23. Descriptive statistics such as mean and standard deviation were used to present demographic data and clinical profile of the patients. Frequency distributions were used to present categorical data. Chi-Squared test were used to determine association of categorical variables and *t*-test for continuous variables with type of sporting discipline. A P value of less than .05 is statistically significant. Tukey's HSD test was done for post hoc analysis.

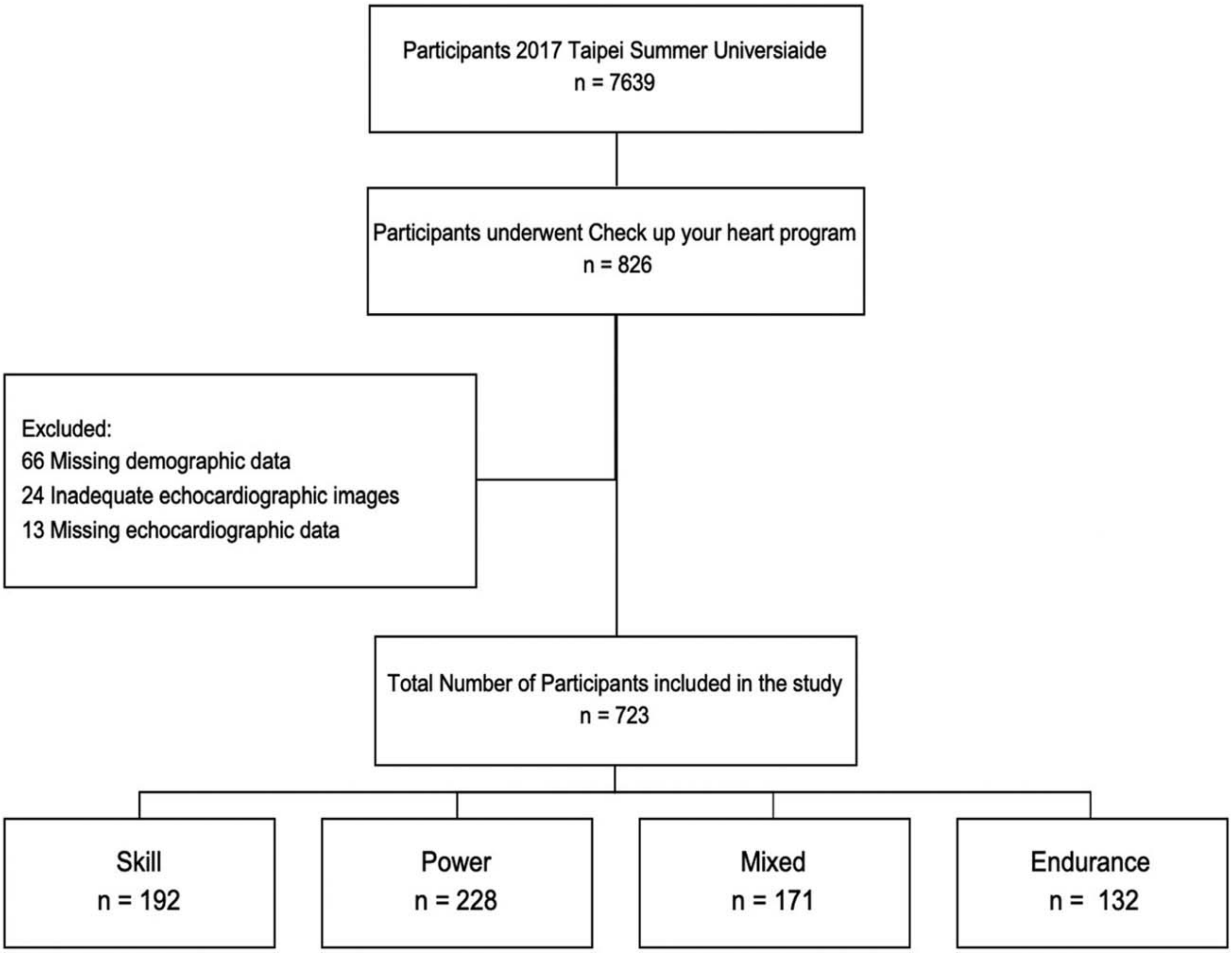

Figure 1. Study design and flow chart for the enrollment of 2017 Taipei Universiade participants.

2.6. Ethical considerations

All the data obtained was treated with utmost confidentiality. The student athletes were assigned an alphanumeric code. The study was limited to participants records and there were no direct contacts with the participants.

2.7. Patient and public involvement

Patients or the public WERE NOT involved in the design, or conduct, or reporting, or dissemination of our research.

3. Results

3.1. Baseline characteristics

After applying exclusion criteria, a total of 723 athletes (mean age 22.6±2.6 years old, male 59%) participated in the Check Up Your Heart Program. These participants were divided into Skill (total participants 182; 26.6%), Power (total 228; 31.5%), Mixed (total 171; 23.7%), and Endurance (total 132; 18.3%). Asian participants were the majority across all 4 sport disciplines (total 31%) (Table 1). Between sporting disciplines, there were significant differences in age ($P<.001$), weight ($P=.032$), body mass index ($P=.016$) body surface area ($P=.031$), and the number of years athlete participation in the national level ($P=.002$). It also showed significant differences in body mass index between the Power ($23.54\pm4.18\,kg/m^2$), and Endurance ($22.47\pm3.63\,kg/m^2$) groups, as well as the body surface area between the Mixed ($1.8\pm0.23\,m^2$) and Skill ($1.87\pm0.22\,m^2$) groups. There was significant differences in the number of years in the national level with Skill group (6.75±4.7 years) in comparison to both the Power (5.58±3.21 years), and Mixed (5.37±3.48 years) groups.

3.2. Electrocardiogram

Using the International consensus for ECG interpretation for athletes, 611 participants (85%) of total 723 participants had normal ECG findings. On the other hand, abnormal ECG findings were found in 1 participant (<1%) of Skill group, 5 (2%) of Power group, 10 (6%) of Mixed group, and 12 (9%) of Endurance group. The Endurance athletes group had a lower number of normal sinus rhythm (18%), and higher number of LVH (39%), and ectopic atrial rhythm (2%) (Table 2). Mean atrial rate was noted to be different between the 4 groups ($P<.001$), with endurance athletes (60±12 bpm) having a lower recorded heart rate in comparison to Skill (65±9 bpm), and Power (65±10 bpm) groups. The QT interval was also longer in

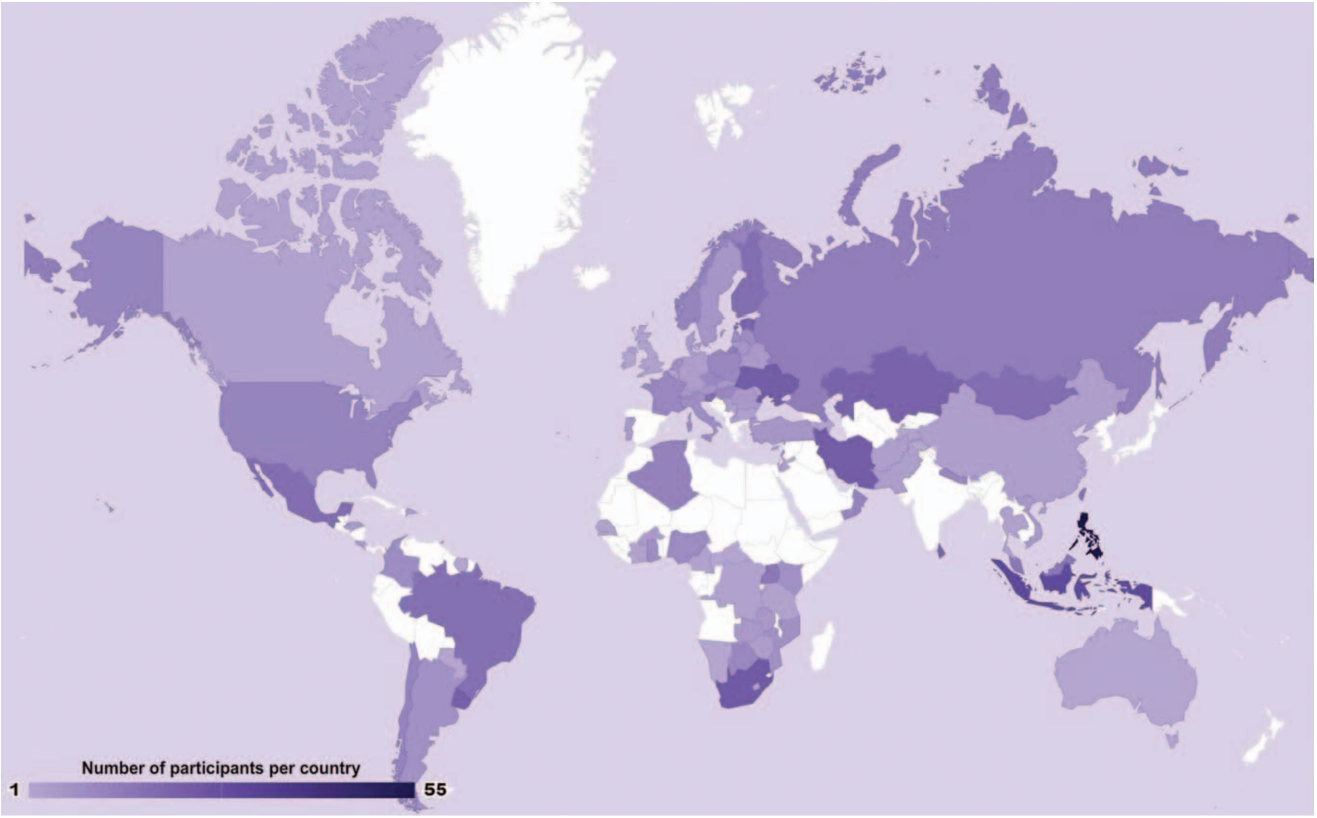

Figure 2. Demographics and distribution of participating countries in 2017 Taipei Summer Universiade.

the Endurance group; however, there were no significant differences in the corrected QT interval.

3.3. 2D Echocardiogram

Two dimensional echocardiographic analysis showed that among 4 sport disciplines, there were significant differences in the following LV measurements: interventricular septum ($P = .044$), LV posterior wall ($P < .001$), LV end-diastolic diameter ($P = .001$), LV end-diastolic volume index ($P < .001$), LV end systolic diameter ($P = .009$), LV end-systolic volume index ($P = .003$), LV stroke volume index ($P < .001$), and LV mass index (LVMI) ($P < .001$) (Table 3). Classification of the left ventricular geometry via LVMI and relative wall thickness showed a significantly higher number of eccentric left ventricular hypertrophy in the Endurance group ($P < .001$) (Fig. 5A). Separating LV geometry into normal and abnormal geometry, there was significant differences among 4 sport disciplines (Fig. 5B). LV end-diastolic volume, LV end-systolic volume, LV stroke volume were significantly higher in the Endurance group compared to the Skill group. LV functions in terms of ejection fraction and GLS did not show any significant difference among the 4 groups. The values of mitral E velocity were significant higher in the Skill group (94.17 ± 18.04 cm/s) as compared to the Mixed (88.96 ± 16.42 cm/s) or Endurance (87.14 ± 17.52 cm/s) group, while the rest of the diastolic function indices were not different across the sport disciplines (Table 4).

RV basal diameter ($P < .001$) and proximal outflow diameter ($P = .007$) were significantly different across the 4 groups. TAPSE in Endurance group was significantly higher than Skill group ($P = .003$). RV basal diameters of the Endurance (37.1 ± 6.3 mm) and Mixed (36.4 ± 5.4 mm) groups were larger compared to the Skill (34.5 ± 5.0 mm), and Power groups (34.8 ± 5.9 mm), while there is a significant increase in the excursion of the tricuspid lateral annular plane in the Endurance (26.7 ± 4.9 mm) group as compared to the Skill (24.77 ± 4.35) group. The Endurance group has the highest percentage of RV dilatation (28%).

LA volume index (LAVI) was significant different across the group ($P = .018$), with note of higher frequency of LA dilatation by LAVI in the Endurance group. Post hoc testing showed that the Mixed group (25.5 ± 12.0 ml) has a larger indexed LA volume compared to that of the Skill group (22.5 ± 9.1 ml/m^2). Right atrial end systolic area is also different among the 4 groups ($P < .001$), with area of the Endurance group (18.3 ± 5.1 cm^2) larger than Skill (15.7 ± 3.4 cm^2), Power (16.1 ± 4.2 cm^2), and Mixed (16.8 ± 3.8 cm^2) groups. Endurance group has the highest percentage of RA dilatation (48%).

The ability of electrocardiogram and echocardiogram to distinguish chamber size and hypertrophy were assessed in the 4 sport disciplines. An electrocardiogram using criteria of LVH was shown to be significantly different among Skill, Power, Mixed, Endurance trained athletes ($P = .0025$), but not LAE, RVH, RAE (P = ns) (Fig. 6A). Echocardiographic evaluation of the chamber sizes showed no difference among the 4 disciplines, but there were significant differences in LA dilatation ($P = .0260$), RV dilatation ($P = .0004$), and RA dilatation ($P = .0002$) (Fig. 6B).

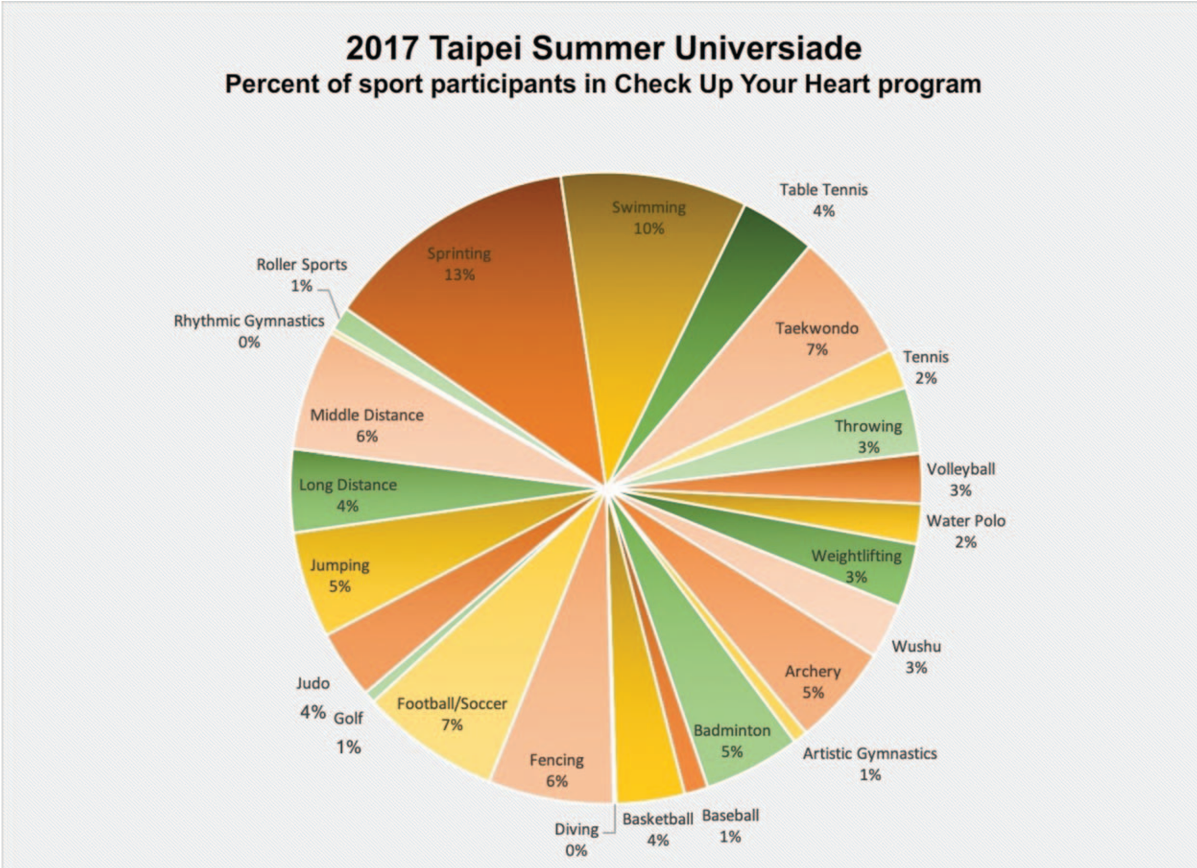

Figure 3. Sport categories of the participants who signed up for the Check Up Your Heart program.

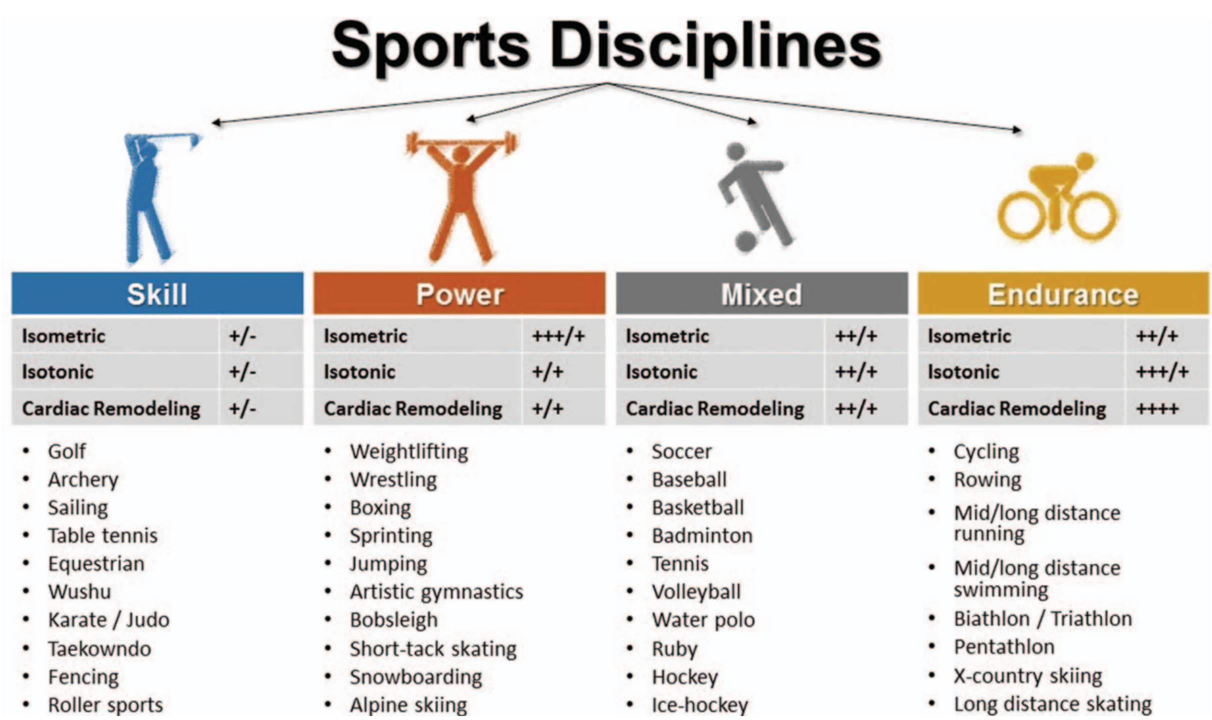

Figure 4. Sport disciplines, according to the relative isometric and isotonic components of exercise, and the resulting cardiac remodeling.

Table 1

Baseline Characteristics of Universiade Athletes Participated in the Check-Up Your Heart Program (n = 723).

Characteristics	Skill n = 192 (%)	Power n = 228 (%)	Mixed n = 171 (%)	Endurance n = 132 (%)	Total n = 723	*P* Value
Age (years)	22.17 ± 2.82	23.11 ± 2.38	22.7 ± 2.27	21.95 ± 2.77	22.55 ± 2.59	<.001
Gender:						.506
Male	108 (57)	126 (57)	100 (59)	85 (64)	419 (59)	
Female	80 (43)	97 (44)	71 (42)	47 (36)	295 (41)	
Weight (kgs)	68 ± 13.86	70.94 ± 15.14	71.74 ± 13.21	68.35 ± 14.87	69.87 ± 14.37	.032
Height (cm)	172.57 ± 10.84	173.26 ± 10.05	175.45 ± 11.27	173.91 ± 11.09	173.72 ± 10.78	.073
Body Mass Index (kg/m^2)	22.66 ± 3.09	23.54 ± 4.18	23.18 ± 2.86	22.47 ± 3.63	23.03 ± 3.54	.016
Body Surface Area (m^2)	1.8 ± 0.23	1.84 ± 0.23	1.87 ± 0.22	1.81 ± 0.23	1.83 ± 0.23	.031
Race						<.001
Asian	87 (45)	53 (23)	37 (22)	44 (33)	221 (31)	
Black	9 (5)	42 (18)	31 (18)	7 (5)	89 (12)	
Caucasian	33 (17)	59 (26)	31 (18)	34 (26)	157 (22)	
Hispanic	13 (7)	15 (7)	22 (13)	7 (5)	57 (8)	
Middle Eastern	12 (6)	9 (4)	9 (5)	14 (11)	44 (6)	
Native American	6 (3)	4 (2)	2 (1)	3 (2)	15 (2)	
Pacific Islander	0	1 (<1)	0	0	1 (<1)	
Others	32 (17)	45 (20)	38 (22)	23 (17)	138 (19)	
Previous Heart Disease	4 (2)	5 (2)	1 (<1)	0	10 (1)	.220
History of chest pain	22 (12)	19 (8)	16 (9)	10 (8)	67 (9)	.618
History of Syncope/Near Syncope	9 (5)	8 (4)	8 (5)	8 (6)	33 (5)	.735
History of SOB/fatigue/palpitations during exercise	17 (9)	32 (14)	9 (5)	15 (12)	73 (10)	.031
History of heart murmur	9 (5)	10 (4)	4 (2)	5 (4)	28 (39)	.662
History of high blood pressure	8 (4)	17 (8)	5 (3)	4 (3)	34 (5)	.111
History of restriction to sports	7 (4)	9 (4)	4 (2)	3 (2)	23 (3)	.725
History of heart testing	36 (19)	47 (21)	23 (14)	22 (17)	128 (18)	.297
Family history of young death than 50 years of age due to cardiac condition	14 (7)	11 (5)	6 (4)	5 (4)	36 (5)	.340
Family history of disability due to a cardiac condition	14 (7)	15 (7)	12 (7)	11 (8)	52 (7)	.941
Family history of genetic cardiac disorder	24 (13)	18 (8)	16 (9)	15 (11)	73 (10)	.427
Average training hours per days						.167
0 to 5 hours/day						
> 5 hours/day	157 (84)	196 (90)	142 (90)	107 (86)	602 (87)	
	31 (17)	22 (10)	16 (10)	18 (19)	87 (13)	
Average training days/week	5.24 ± 1.74	5.47 ± 1.05	5.46 ± 2.85	5.77 ± 1.16	5.43 ± 1.83	.073
Average training months/year	12.96 ± 25.12	10.51 ± 2.35	11.52 ± 13.17	13.02 ± 25.36	11.86 ± 18.1	.462
No. of years in sports	10.6 ± 4.7	10.20 ± 4.94	11.45 ± 4.63	10.9 ± 4.61	10.76 ± 4.76	.103
No. of years in national level	6.75 ± 4.7	5.58 ± 3.21	5.37 ± 3.48	6.03 ± 3.34	5.92 ± 3.77	.002
% of Dynamic/Endurance training						.002
0%						
25%	0	6 (3)	2 (1)	1 (<1)	9 (1)	
50%	21 (11)	30 (13)	20 (12)	9 (7)	80 (11)	
75%	59 (31)	64 (28)	36 (21)	17 (13)	176 (24)	
100%	89 (46)	102 (45)	84 (49)	80 (61)	355 (49)	
	23 (12)	26 (11)	28 (17)	25 (19)	102 (14)	
% of Static/Strength training						.453
0%						
25%	2 (1)	3 (1)	1 (<1)	2 (2)	8 (1)	
50%	33 (17)	49 (22)	34 (20)	39 (30)	155 (22)	
75%	78 (41)	72 (32)	62 (37)	38 (29)	250 (35)	
100%	63 (33)	82 (36)	59 (35)	40 (30)	244 (34)	
	16 (8)	22 (10)	14 (8)	13 (10)	65 (9)	
% of Skill/Other training						.066
0%						
25%	132 (69)	165 (72)	100 (59)	95 (72)	492 (68)	
50%	11 (6)	11 (5)	16 (9)	10 (8)	48 (7)	
75%	20 (10)	17 (8)	17 (10)	2 (2)	56 (8)	
100%	19 (10)	26 (11)	27 (16)	19 (14)	91 (13)	
	10 (5)	9 (4)	10 (6)	6 (5)	31 (5)	

Table 2

Electrocardiographic Findings of Universiade Athletes in the Check-Up Your Heart Program (n = 723).

ECG findings	Skill n = 192 (%)	Power n = 228 (%)	Mixed n = 171 (%)	Endurance n = 132 (%)	Total n = 723	*P* value
ECG Classification						<.001
Normal	174 (91)	201 (88)	132 (77)	104 (79)	611 (85)	
Borderline	17 (9)	22 (10)	29 (17)	16 (12)	84 (12)	
Abnormal	1 (<1)	5 (2)	10 (6)	12 (9)	28 (4)	
Atrial Rate (beats/min)	65.4 ± 9.48	65.21 ± 10.22	63.3 ± 10.76	60.47 ± 11.76	63.94 ± 10.6	<.001
P Axis	50.98 ± 19.81	48.96 ± 21.83	49.35 ± 23.57	53.05 ± 23.53	50.32 ± 22.06	.350
PR Interval (ms)	153.76 ± 27.87	152.13 ± 27.35	158.99 ± 27.90	154.72 ± 29.79	154.66 ± 28.13	.110
QRS duration (ms)	91.17 ± 11.15	90.32v11.4	90.94v12.33	94.09 ± 8.61	91.38 ± 11.17	.017
QT interval (ms)	398.86 ± 27.32	397.83 ± 29.83	407.94 ± 29.89	413.86 ± 33.84	403.42 ± 30.59	<.001
QTC (ms)	413.15 ± 23.35	411.4 ± 21.88	414.77 ± 25.25	411.11 ± 25.29	412.61 ± 23.73	.452
R Axis	69.85 ± 20.43	65.47 ± 24.23	70.25 ± 24.43	68.62 ± 29.89	68.34 ± 24.53	.179
Normal	58 (30)	77 (34)	46 (27)	24 (18)	205 (28)	.015
Left Ventricular Hypertrophy	49 (26)	46 (20)	46 (27)	51 (39)	192 (27)	.002
Right Ventricular Hypertrophy	1 (<1)	3 (1.3)	3 (1.8)	2 (1.5)	9 (1)	.737
Incomplete right bundle branch block	6 (3)	3 (1)	2 (1)	2 (2)	13 (2)	.448
Early repolarization pattern	10 (5)	11 (5)	20 (12)	6 (5)	47 (7)	.019
Sinus bradycardia <60 bpm	54 (28)	65 (29)	54 (32)	57 (43)	230 (32)	.017
Sinus arrythmia	60 (31)	69 (30)	39 (23)	34 (26)	202 (28)	.240
Ectopic Atrial Rhythm	0	0	0	2 (2)	2 (<1)	.030
1st degree AV block	2 (1)	6 (3)	7 (4)	4 (3)	19 (3)	.333
Left Axis deviation	0	1 (<1)	1 (<1)	3 (2)	5 (<1)	.094
Right Axis deviation	0	3 (1)	1 (<1)	1 (<1)	5 (<1)	.446
Left Atrial Enlargement	2 (1)	0	0	0	2 (<1)	.136
Right Atrial Enlargement	0	1 (<1)	2 (2)	3 (2)	7 (1)	.112
Complete right bundle branch block	1 (<1)	1 (<1)	0	0	2 (<1)	.689
T wave inversion	0	3 (1)	3 (2)	2 (2)	8 (1)	.377
ST segment depression	2 (1)	0	0	0	2 (<1)	.136
Pathologic Q waves	0	0	1 (<1)	1 (<1)	2 (<1)	.414
Ventricular preexcitation	0	0	1 (<1)	0	1 (<1)	.357
Prolonged QT duration	1 (<1)	0	1 (<1)	3 (2)	5 (<1)	.090
Brugada type pattern 1	0	1 (<1)	2 (1)	0	3 (<1)	.295

Table 3

Echocardiographic Findings of Universiade Athletes in the Check-Up Your Heart Program (n = 723).

Echo findings	Skill n = 192 (%)	Power n = 228 (%)	Mixed n = 171 (%)	Endurance n = 132 (%)	Total n = 723	*P* value
Interventricular septum (mm)	9.58 ± 1.74	9.75 ± 1.89	9.91 ± 2.05	10.19 ± 2.11	9.83 ± 1.94	.044
LV posterior wall (mm)	7.99 ± 1.47	8.22 ± 1.51	8.54 ± 1.61	8.85 ± 1.7	8.36 ± 1.59	<.001
LV End diastolic diameter (mm)	48.17 ± 5.79	49.15 ± 5.49	49.4 ± 5.65	50.76 ± 5.05	49.26 ± 5.58	.001
LV End systolic diameter (mm)	28.8 ± 4.820	29.97 ± 4.58	30.12 ± 4.94	30.50 ± 5.03	29.8 ± 4.85	.09
LV End diastolic volume index (ml/m^2)	6.16 ± 12.74	62.68 ± 12.59	62.49 ± 13.34	68.58 ± 13.42	63.34 ± 13.2	<.001
LV End systolic volume index (ml/m^2)	18.43 ± 5.96	19.53 ± 6.17	19.61 ± 6.9	21.22 ± 7.22	18.58 ± 6.56	.003
Stroke volume index (ml/m^2)	42.73 ± 10.39	43.15 ± 9.71	42.88 ± 9.72	47.35 ± 10.11	43.76 ± 10.1	<.001
LV ejection Fraction (%)	69.95 ± 7.81	68.89 ± 7.32	68.84 ± 7.93	69.13 ± 8.21	69.2 ± 7.76	.485
LV global longitudinal strain (%)	20.82 ± 3.35	20.77 ± 3.12	20.45 ± 3.18	20.65 ± 3.09	20.68 ± 3.19	.725
LV GLS						.903
>15%	153 (95.6)	177 (94)	153 (94)	115 (94)	598 (95)	
<15%	7 (4)	11 (6)	10 (6)	7 (6)	35 (6)	
LV mass index	80.72 ± 16.45	84.59 ± 19.34	87.32 ± 21.79	97.74 ± 24.28	86.69 ± 21.06	<.001
Relative wall thickness	0.34 ± 0.07	0.34 ± 0.07	0.35 ± 0.07	0.35 ± 0.07	0.34 ± 0.07	.146
LV Geometry						<.001
Normal	164 (90)	195 (89)	141 (83)	93 (71)	593 (84)	
Remodeling	10 (5)	13 (6)	13 (8)	6 (5)	42 (6)	
Concentric Hypertrophy	2 (1)	3 (1)	5 (3)	9 (7)	19 (3)	
Eccentric Hypertrophy	6 (3)	9 (4)	12 (7)	23 (18)	50 (7)	
Left atrial volume index	22.45 ± 9.07	22.89 ± 10.01	25.53 ± 11.98	25.15 ± 11.39	23.89 ± 10.67	.018
RA End systolic Area (cm2)	15.71 ± 3.35	16.06 ± 4.18	16.8 ± 3.75	18.28 ± 5.05	16.56 ± 4.16	<.001
RV plax (mm)	29.35 ± 5.99	30.08 ± 5.15	30.85 ± 5.8	30.83 ± 5.23	30.22 ± 5.58	.042

(*continued*)

Table 3

(continued).

Echo findings	Skill n=192 (%)	Power n=228 (%)	Mixed n=171 (%)	Endurance n=132 (%)	Total n=723	*P* value
RV proximal (mm)	30.04±6.57	31.04±6.11	32.34±6.94	31.76±5.97	31.24±6.46	.007
RV base (mm)	34.52±4.97	34.77±5.85	36.38±5.41	37.51±6.29	35.61±5.73	<.001
TAPSE (mm)	24.77±4.35	25.46±4.86	25.65±5	26.71±4.94	25.56±4.81	.006
RV Longitudinal strain (%)	24.01±4.56	24.28±4.86	23.96±4.69	24.04±4.75	24.08±4.72	.922
RV GLS						.578
>20%	135 (79)	164 (85)	131 (81)	100 (82)	530 (82)	
<20%	35 (21)	29 (15)	30 (19)	22 (18)	116 (18)	
Mitral E Velocity (cm/s)	94.17±18.04	91.40±17.83	88.96±16.42	87.14±17.52	90.73±17.64	.002
Mitral A Velocity (cm/s)	47.11±11.06	47.24±10.22	46.31±11.31	45.82±10.81	46.71±10.81	.595
Mitral E/A	2.09±0.59	2.0±0.51	2.02±0.58	2.0±0.63	2.02±0.57	.405
E' Medial Annulus (cm/s)	14.18±2.27	13.84±2.39	13.86±2.23	13.94±2.43	13.95±2.33	.463
E' Lateral annulus (cm/s)	17.93±3.2	17.73±3.06	17.37±2.73	17.7±2.96	17.69±3.0	.375
Average E/E'	5.89±1.27	5.86±1.16	5.75±1.05	5.56±1.09	5.78±1.15	.054
Tricuspid regurgitation jet (cm/s)	1.68±0.54	1.70±0.51	1.74±0.48	1.78±0.49	1.72±0.51	.374
RA Dilatation	44 (25)	64 (30)	58 (35)	62 (48)	228 (33)	<.001
LA Dilatation	17 (11)	25 (13)	32 (20)	27 (22)	101 (16)	.026
RV Dilatation	18 (10)	33 (15)	35 (21)	36 (28)	122 (18)	<.001
LV Dilatation	10 (5)	16 (7)	11 (6)	13 (10)	5 (7)	.477

4. Discussions

To the best of our knowledge, this is the first large study where elite university athletes competed at Summer Universiade were evaluated for cardiac remodeling according to the newly proposed 4 sport disciplines proposed by the EAPC and EACVI in 2018. Our findings were:

1. among the abnormal LV geometry, eccentric LVH is the most common abnormal LV geometry among the University athletes (7%). In addition, abnormal LV geometry was significantly different among 4 sport disciplines.
2. In terms of chamber dilatations, LV dilatation was not significant different but LA dilatation, RV dilatation, and RA dilatation were significant different among 4 sport discipline, with RA dilatation being most discriminative.
3. LV ejection fraction, LV strain, and RV strain showed no difference in 4 sport disciplines.

4.1. Electrocardiogram

According to a review by De In-nocentiis et al, abnormal ECG findings are commonly observed in competitive athletes (nearly 15%), and are more frequently seen among Endurance athletes than Strength (Power) athletes.[11] Similarly, this study showed that abnormal ECG findings, including early repolarization, increased QRS voltage and sinus bradyarrhythmias, were common among Endurance athletes. This seems to be related to the higher cardiac output acquired during endurance exercise resulting in remodeling: increase cardiac dimensions and thickness.[12] Similar changes in QRS duration, early repolarization pattern, LVH, and sinus bradycardia considered as normal ECG findings in athletes, were noted in this study (Table 2). Endurance athletes have a slower heart rate in comparison to Skill and Power groups. Resting heart rate of those people who had long term training was influenced by the heightened parasympathetic activity of the heart.[13] Cardiac autonomic conditioning such as increased in vagal tone and/or withdrawal of sympathetic activity can also explain early repolarization pattern.[14] Moreover, ECG of athletes often exhibit LVH which may reflect increase chamber size.[12] There was no significant difference in the ECG alterations classified under the borderline type, maybe because there were very few subjects with these findings under this category. However, borderline ECG findings are most commonly seen among athletes under the Mixed type of sports. In such athletes, the cardiac remodeling shows increase in LV cavity and modest changes in LV wall thickness and LV mass.[7]

4.2. 2D Echocardiogram

The type of sport discipline can influence the alteration in cardiac remodeling. Likewise, duration of training and intensity of exercise conditioning can affect cardiac structural change. In 2015 Gwangju Summer Universiade study, concentric LV remodeling (6.2%) was the most common abnormal LV geometry. In contrast to their finding, the present study showed that eccentric LVH was the most common abnormal LV geometry (7%), especially in Endurance group, followed by LV remodeling (3%) (Fig. 3). Similar to 2015 Gwangju Summer Universiade study,[6] abnormal LV wall thickness (>12 mm) among athletes is less common in this study.

LAVI was significantly different across the group. The Endurance group has highest percentage of LA dilatation (Table 3). Similarly, a mild increase in LA diameter (>40 mm) was found in 18% of athletes and marked dilation (>45 mm) in 2%.[15] This structural changes are seen among cyclist, rowers and canoeist (combined dynamic and static exercise) showing the greatest impact.[16]

The right ventricle is more prone to geometric changes as an adaptation process for high level repetitive training.[17] The present study showed that the RV basal diameters of the Endurance and Mixed groups were larger compared to those of the Skill and Power groups, while TAPSE was significantly higher

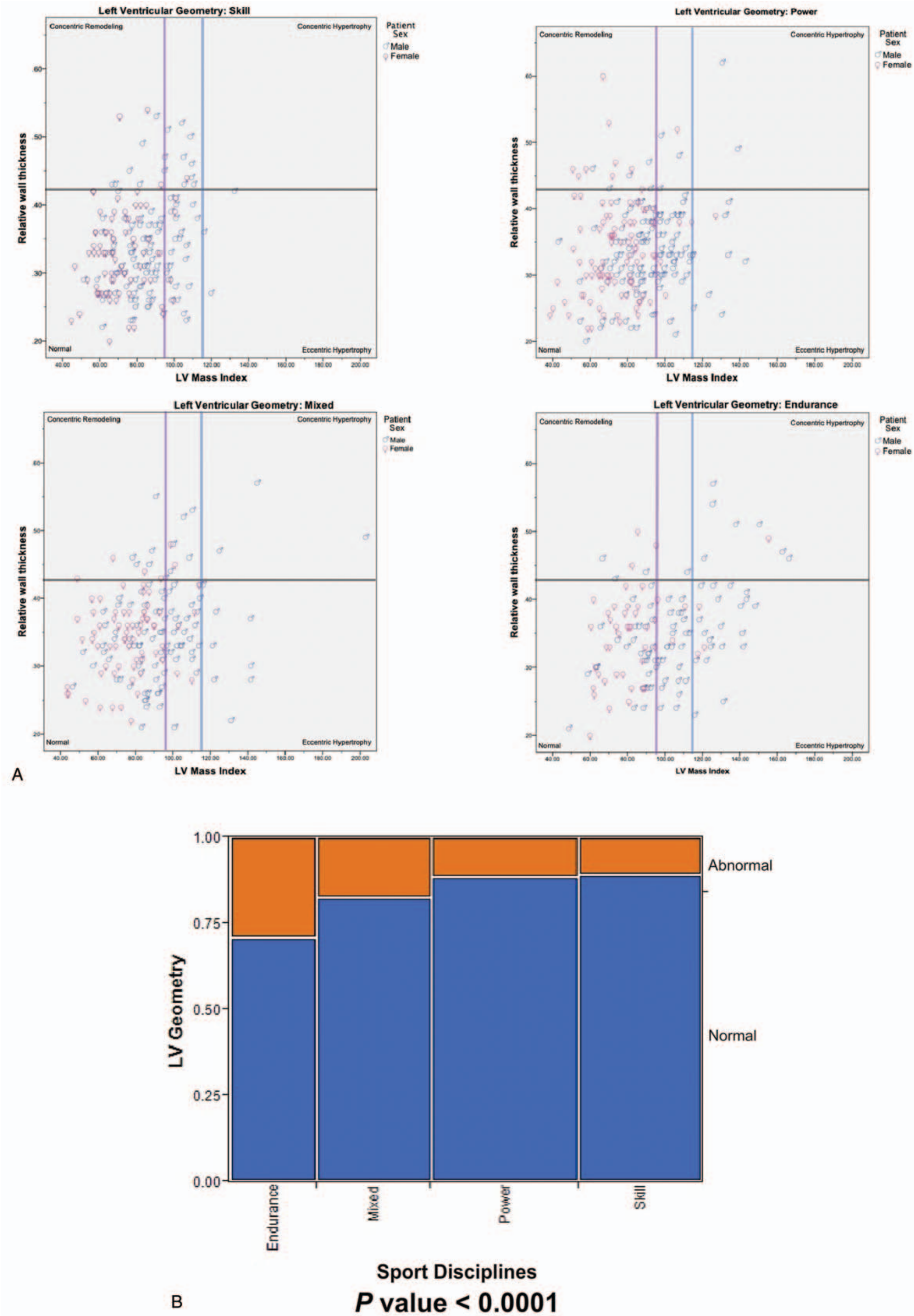

Figure 5. Patterns of LV geometry based on measurement of LVMI and RWT, separated participants into normal, and abnormal geometry: concentric remodeling, eccentric hypertrophy, and concentric hypertrophy (A). Percentage of normal and abnormal LV geometry in in 4 sport disciplines (B). LV = left ventricular, LVMI = left ventricular mass index, RWT = relative wall thickness.

Table 4

Comparison of Power, Mixed, Endurance Athletes to Skill Athletes as Reference.

Between groups comparison (Skill)	Power n=228 (%)	Mixed n=171 (%)	Endurance n=132 (%)
Electrocardiographic Findings			
Atrial rate	0.998	0.226	<.001
P Axis	0.787	0.896	.847
PR interval	0.935	0.289	.991
QRS duration	0.866	0.997	.093
QT interval	0.985	0.021	<.001
QT corrected	0.875	0.917	.871
R Axis	0.261	0.99	.971
Echocardioraphic Findings			
Interventricular septum (mm)	0.823	0.206	.032*
LV posterior wall (mm)	0.493	0.005*	<.001*
LV End diastolic diameter (mm)	0.294	0.158	<.001*
LV End systolic diameter (mm)	0.076	0.051	.011*
LV End diastolic volume (ml)	0.382	0.214	.001*
LV End diastolic volume index (mL/m^2)	0.642	0.767	<.001*
LV End systolic volume (ml)	0.220	0.103	.009*
LV End systolic volume index (ml/m^2)	0.330	0.316	.001*
Stroke Volume (ml)	0.753	0.605	.005*
Stroke volume index (mL/m^2)	0.974	0.999	<.001*
LV ejection Fraction (%)	0.517	1.000	.992
LV global longitudinal strain (%)	0.999	0.724	.971
LV mass index	0.227	0.012*	<.001*
Relative wall thickness	0.997	0.351	.439
Left atrial volume index	0.981	0.050	.147
RA End systolic Area (cm2)	0.883	0.281	<.001*
RV plax (mm)	0.577	0.060	.098
RV proximal (mm)	0.424	0.005*	.096
RV base (mm)	0.973	0.013*	<.001*
TAPSE (mm)	0.487	0.317	.003*
Mitral E Velocity (cm/s)	0.394	0.028	.003*
Mitral A Velociy (cm/s)	0.999	0.900	.725
Mitral E/A	0.426	0.645	.516
E Medial Annulus (cm/s)	0.438	0.589	.808
E Lateral annulus (cm/s)	0.908	0.302	.908
Tricuspid regurgitation jet (cm/s)	0.878	0.995	.997

in the Endurance group as compared to the Skill group. The prevalence of RV dilatation were also higher in the Endurance group (Table 3), relating to the hemodynamic changes that occurred.[18] The duration and the intensity of endurance exercise are linearly associated with the RV filling and eventual increase in RV and RA chambers.[18] Despite significant RV enlargement, athletes usually have normal RV systolic function.[7]

Elite athlete differed from subelite athlete in having greater LV and RV end-diastolic volumes.[19] Pathologic LVH leads to LA dilatation with LA dysfunction, whereas LA dilatation as a result of endurance training is an adaptive and healthy physiologic response.[20] However, there were no study that directly compared the 4 chamber dilatations including RA size in this population of high-performance athletes.[21–23] Our results showed that the 4 chamber dilatations had increasing differences in the order of LV, LA, RV, and RA. RA size among all chambers, was most responsive to the rigor of sport training, and therefore participants in Endurance discipline showed the largest RA dilatation. These results suggest that dilatation of right atrium, with the least pressure among all 4 chamber, was most strongly associated with physiological adaptation due to the hemodynamic demands of the type of sport discipline. Such sport activity and intensity level-associated cardiac remodeling was followed by the dilatation of right ventricle, left atrium, and least with left ventricle.

Longitudinal strain derived from two-dimensional speckle tracking echocardiography can detect subtle physiological difference in Endurance athletes vs control subjects.[24] In addition, previous athlete studies suggest potential value of strain analysis alongside standard echocardiographic measurements.[25] In a study to determine the relationships of field position (linemen vs nonlinemen) and acquired LVH among American-style football players in NCAA games, nonlinemen demonstrated eccentric LVH and increased GLS while linemen developed concentric LVH with decreased GLS.[26] It was suggested that physiologic adaptions in endurance training should be accompanied by eccentric LVH, and further work may be required to evaluate whether concentric remodeling is pathologic rather than adaptive.[26] In our study, although types of LV geometry differed among 4 sport disciplines, LV GLS was not significantly different among the 4 sport disciplines. The RV has different morphologic characteristics than the LV, however, deformation analysis of the RV is feasible and is gaining popularity.[27] In the present study, we also showed that there was no significant difference in terms of RV GLS among the 4 sport disciplines.

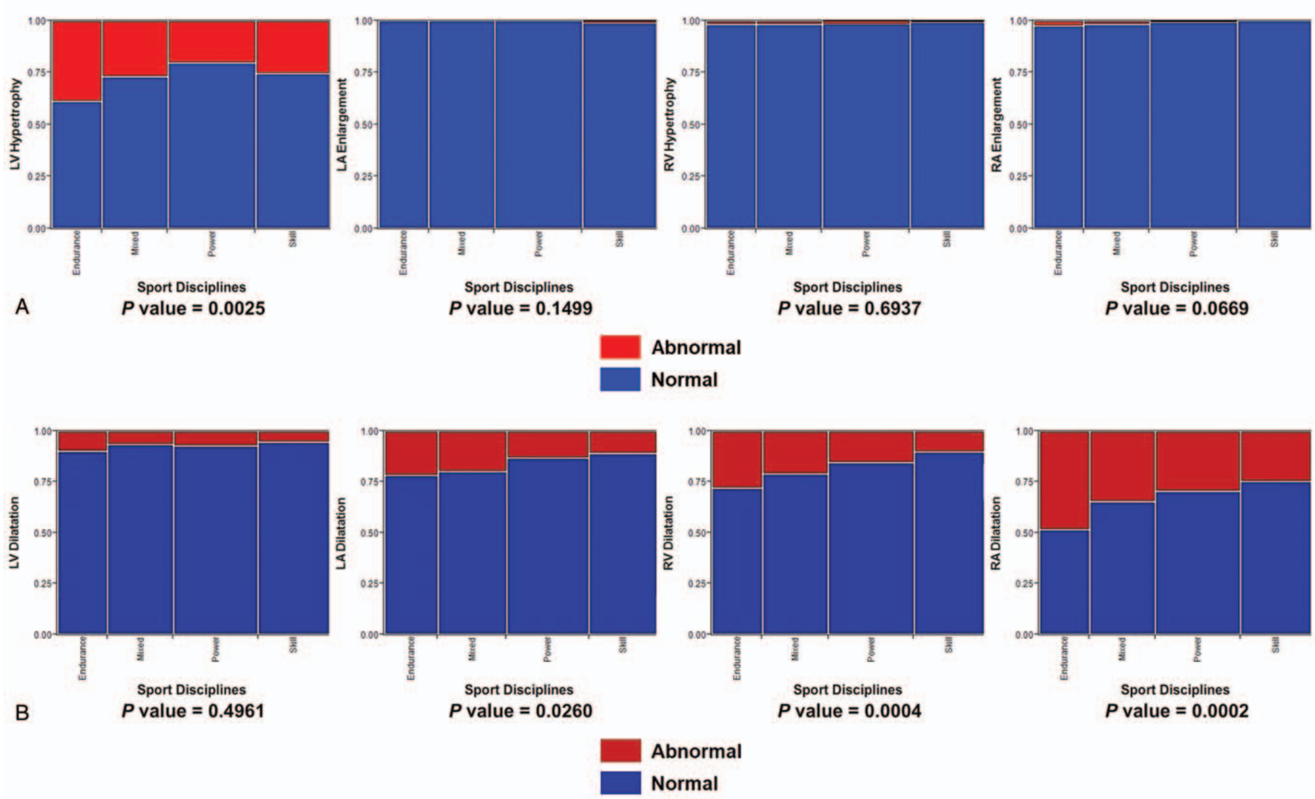

Figure 6. Adaptive changes in chamber wall thickness and size in the 4 sport disciplines assessed by electrocardiogram (A) and echocardiogram (B).

In summary, in the 2017 Taipei Summer Universiade, electrocardiographic determination of LVH was significantly different in the 4 sport disciplines. In addition, echocardiographic assessment of LVH along with LA, RV, RA chamber dilatations were significantly different in the 4 sport disciplines, with RA size being most discriminative.

5. Limitations

First, since the athletes voluntarily participated in the Check Up Your Heart program, there were be selection biased. Second, only single vendor ultrasound machine was used, the measurements could be biased. However, due to all patients using the same vendor with images analyzed by the same vendor-independent software, intervendor variability of 2D strain could be eliminated.[28] However, intraobserver and interobserver variability during measurements could still occur. Third, since this is a cross-sectional study, a longitudinal follow up was not possible, and the clinical significance of chamber dilatations due to the difference of physical intensity level in 4 sport disciplines could not be answered. Last, the chamber dilatation utilized different measurement methods described by ASE guideline, and thus conclusion drawn from these measurements may warrant further studies.

6. Conclusion

In the elite university athletes who competed in the multidisciplinary sports in 2017 Taipei Summer Universiade, eccentric LVH was the most common type of cardiac remodeling. Adaptive changes in chamber size were more commonly seen in Endurance sport. RA dilatation was the most sensitive to hemodynamic demand, followed by RV dilatation, LA dilatation, and LV dilatation. LV ejection fraction, LV GLS, and RV GLS did not show any significant difference across the 4 sport disciplines.

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