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Left Ventricular Hypertrophy in Male and Female Judo Athletes

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ABSTRACT

Changes in cardiac geometry develop after intense and prolonged training. Left ventricular enlargement, increased relative wall thickness, and growing mass of the left ventricle occur after strenuous exercise. Combat sports such as judo can lead to left ventricular hypertrophy. Previous studies have found that there are differences in left ventricular chamber size and thickness between the sexes, with female athletes having smaller wall diameters and less hypertrophy than male athletes. The research aims to examine heart muscle adaptations and remodeling of cardiac geometry among elite judo athletes and to evaluate differences between males and females. A cross-sectional study included a group of 19 (males n = 10, females n = 9) professional judokas between 20 and 30 years. Demographic and anthropometric data were collected. Cardiac geometry was determined by two-dimensional transthoracic echocardiography. In terms of left ventricular mass and the left ventricular mass index significant differences were found between male and female judokas (233.44 ± 68.75 g vs. 164.11 ± 16.59 g, p = 0.009), (105.16 ± 24.89 vs. 84.66 ± 15.06, p = 0.044), respectively. A greater enlargement of the heart muscle is observed in male athletes compared to the female group. Left ventricle enlargement is likely to occur among elite-level judokas.

Introduction

Physiological and pathological remodeling, depending on the growth, exercise, or special situations such as pregnancy in the first case, or as a result of inflammation, ischemia, or various stresses such as biomechanical stress in the second case, refer to geometric alterations in the heart muscle [1]. Pathological cardiac remodeling is the process of various negative factors leading to structural, functional changes in the left ventricle (LV) in response to internal or external cardiovascular damage or as a result of various pathogenic risk factors, and often anticipates clinical heart failure (HF) [1].

The cardiovascular system adapts in response to the hemodynamic stress to which the body is exposed during training. Athletic training leads to LV remodeling and physiological adaptation of heart morphology and function. A pattern of LV geometry is highly dependent on the type of sport, gender, age, comorbidities, and other factors [2–4]. These morphological changes depend especially on the type of training and are clinically characterised by changes in size and cardiac shape due to increased load [5].

Distinguishing athletic cardiac remodeling from pathological remodeling, and thus from cardiomyopathy, is important and a frequent medical question. Cardiac magnetic resonance imaging (CMR) plays a crucial role in clinical aid as it can help physicians discriminate a physiological event from a pathological one where electrocardiogram (ECG) and echocardiography alone leave several uncertainties. CMR can more accurately assess cardiac structure and function, as well as thoroughly evaluate the myocardium by detecting crucial changes such as myocardial scarring and/or diffuse fibrosis [6].

Judo is an intermittent combat sport that requires high levels of intramuscular strength. Training at a competitive level requires full-body engagement and a wide range of both tactical and technical skills to compete at an elite level and it can therefore cause an adaptation of the geometry of the heart over time [7, 8]. There are studies indicating a difference in the increase in relative wall thickness (RWT) and LV cavity size between genders, i. e. smaller RWT was observed, as well as the size of its cavities in female than in male athletes [9]. However, the number of studies and data on gender-specific changes in LV myocardial geometry in combat sports athletes is very limited [10].

Elite judokas regularly implement physically and physiologically demanding training to remain internationally competitive.

Extreme physical exertion requires aerobic and anaerobic energy sources to provide adequate energy during training and competition [11].

Previous studies have shown that during intense and strenuous training in judokas, the heart muscle undergoes significant adaptations [12, 13]. Long-term athletic training is associated with a series of alterations in cardiac structure, function and electrical activity that collectively refer to the broadly defined athlete's heart [2, 14].

However, the clinical profile of the athlete's heart has greatly expanded over the years following the increased accessibility and monitoring of athletes systematically using echocardiography.

Although several studies have evaluated cardiac response to regular exercise training in male athletes, there is limited data on females, who still make up an ever-growing number of elite athletes worldwide. A previous comprehensive study carried out on Italian Olympians revealed that none of the athletes showed absolute RWT greater than the expected upper limits for the general population, and the LV cavity was found to be enlarged in only 8 % of athletes [15].

The purpose of the present investigation is to examine gender differences in adaptations of cardiac ventricular geometry among elite judo athletes.

Materials and Methods

We conducted a cross-sectional study at the Vojvodina Cardiovascular Disease Institute (IKVB) in Sremska Kamenica, Serbia, which included a total of 19 respondents divided into two groups. The data was collected by inspecting the electronic records of the respondents through the IKVBV computer system. Written informed consent was obtained from each subject and all procedures were performed and conducted according to the guidelines of the Declaration of Helsinki and approved by both the Institutional Review Board of the Faculty of Sport and Physical Education of the University of Novi Sad, Serbia (Ref. n. 46–06–02/2020–1).

Participants

The study included 19 elite judokas divided into 2 subgroups, the first group consisted of 10 male athletes (mean age: 25.50 ± 3.17 years), and the second group consisted of 9 female judokas (mean age: 23.56 ± 3.16 years). All judokas included in this study were members of the national team and participated in national and international competitions, achieving numerous victories in major competitions in their sporting careers, such as the Olympic Games, World Championships and World Cups. The subjects started practicing judo between the ages of six and eight; the average duration of judo training experience was 16.55 ± 3.16 years, with a training volume of 20 to 25 hours per week. Judoka spent 1.5–2 hours training in the weight room two to three times a week. Participants competed for the senior national team of Serbia in international competitions and scored for IJF ranking, achieving the minimum of one ranking. The subjects were of various categories, from 48 kg up to 78 kg. Four of them reached the Olympic standard (10th, 10th, 16th, and 18th place WRL), while two of them came close to the Olympic standard and scored 25th. Three of them participated in the Olympics. All participants underwent a standard 12-lead surface ECG recording at rest, with a paper speed of 25 mm/s and a gain of 10 mm/mV. A cardiologist interpreted each ECG to rule out potential abnormalities. The inclusion criteria were: that the judokas were elite level, had been judoing for at least 10 years continuously, and had no particular heart abnormalities so as to compromise the measurement. Measurements were taken in the early morning hours, before intake of water or food.

Body composition

Demographic, anthropometric, and echocardiographic data were analyzed for all subjects.

Analysis of anthropometric characteristics included measurement of body height (H), performed with a Martin anthropometer, with an accuracy of 0.1 cm, performed in a standing position with heels together and toes apart, with hands close to the body. The position of the head during H measurements was horizontal and the values are expressed in centimeters. Body weight (BW) was determined on a medical scale with an accuracy of 0.1 kg.

Body surface area (BSA) was analyzed according to the appropriate formula: BSA (m^2) = (√ (H (cm)) x BW (kg))/3600

Left ventricular geometry assessment

All subjects underwent two-dimensional transthoracic echocardiography using a 2.5 MHz low-frequency probe on a Vivid 9 ultrasound machine manufactured by General Electric's Co. in the echocardiography department of the Cardiology Clinic of the Institute of Cardiovascular Diseases of Vojvodina.

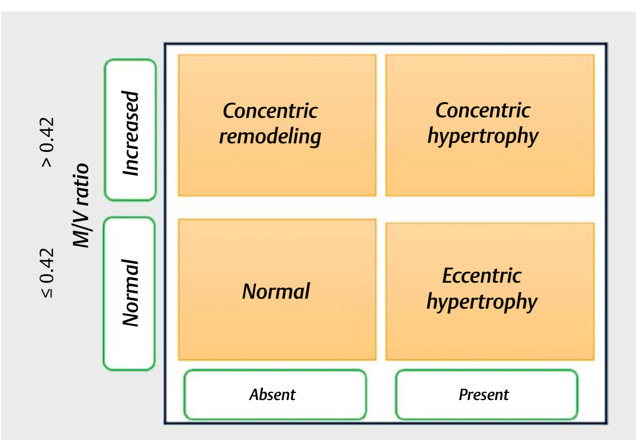
The examination was performed in the supine position. Measurements, and calculations of morphological and functional indicators of the LV chamber were performed according to the standards of the American Association for Echocardiography and the European Association for Cardiovascular Imaging [16]. For every obtained set of data, three consecutive cardiac cycles in an uncompressed format were saved in a cine-loop structure. Subsequently, one researcher, unaware of the patients' clinical details, conducted the analysis offline without any blinding. The following parameters were measured and calculated: LV posterior wall thickness in diastole (PLWd, mm); Interventricular septal thickness in diastole (IVSd, mm); relative wall thickness (RWT, mm) was calculated following the formula: RWT = 2 x PLWd/(end-diastolic diameter) LVIDd (males 52,25 ± 5,80 – females 49,06 ± 2,79) LVMI was calculated using echocardiographic parameters, according to the following Devereux formula, automatically in the software system:

IMVS = 0.8x (1.04 x [(LVIDd + IVSd + PLWd] x 3 – LVIDd x 3) + 0.6. LVMI was calculated by indexing the patient's body surface area (BSA, m^2).

The geometry of the LV is defined according to the RWT and LVMI. (▶ **Fig. 1**)

- Normal geometry *(type 1 remodeling)*: RWT < 0.42 and LVMI ♂ ≤ 115 g/m^2 ♀ ≤ 95 g/m^2.
- Concentric remodeling *(type 2 remodeling)*: RWT ≥ 0.42 and LVMI ♂ ≤ 115 g/m^2 and ♀ ≤ 95 g/m^2.
- Concentric hypertrophy *(type 3 remodeling)*: RWT ≥ 0.42 and LVMI ♂ > 115 g/m^2 ♀ > 95 g/m^2.
- Eccentric hypertrophy *(type 4 remodeling)*: RWT < 0.42 and LVMI ♂ > 115 g/m^2 ♀ > 95 g/m^2.

Regarding the normal range of LVM (g), in accordance with the guidelines and standards' Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging' are 88–224 g in men and 67–162 g in women [16].



▶ **Fig. 1** Left ventricular geometry [16].

▶ **Table 1** Age and anthropometric parameters of judo athletes.

	Males (n = 10)	**Females (n = 9)**	**p value**
	Mean ± SD	**Mean ± SD**	
Age (years)	25.50 ± 3.17	23.56 ± 3.16	0.199
BH (cm)	181.90 ± 8.17	166.55 ± 7.28	**0.000*** **
BM (kg)	82.11 ± 10.43	63.92 ± 13.87	**0.005*** **
BSA (m^2)	2.02 ± 0.16	1.70 ± 0.18	**0.001*** **

Legend: n – number of participants; SD – Standard Deviation; BH – body height; BM – Body mass; BSA – Body surface area; p value – Statistical significance; *** – p<0.01; *** – p<0.001.

Data analysis

The data obtained were sorted into the Microsoft Office Excel package (version 2019, Microsoft Inc. Italy), while the IBM SPSS (Statistical Package for the Social Sciences, version 20.0. IBM Corp.20, Armonk, NY) was used for the statistical analysis. Data processing included descriptive and inferential statistical methods. Numerical characteristics are presented using means. Depending on the nature of the data, the comparison of numerical characteristic values between the two groups was performed using a t-test for independent samples.

The results are presented in tables and graphs. The level of statistical significance was set at $p < 0.05$.

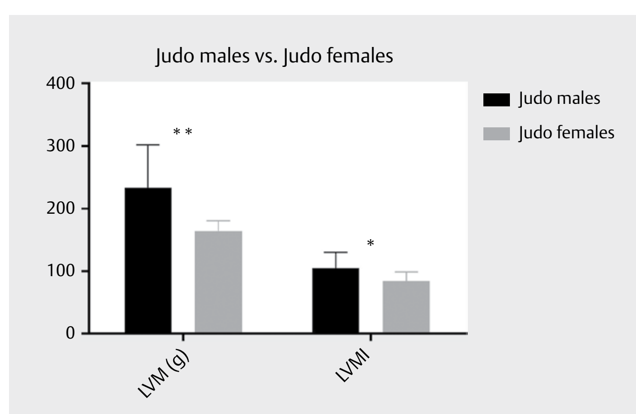
Results

The anthropometric characteristics between the two groups of judokas show significantly higher values in males in terms of BH (181.90 ± 8.17 cm vs. 166.55 ± 7.28 cm), BM (82.11 ± 10.43 kg vs. 63.92 ± 13.87 kg) and BSA (2.02 ± 0.16 m^2 vs. 1.70 ± 0.18 m^2) compared to females (▶ **Table 1**).

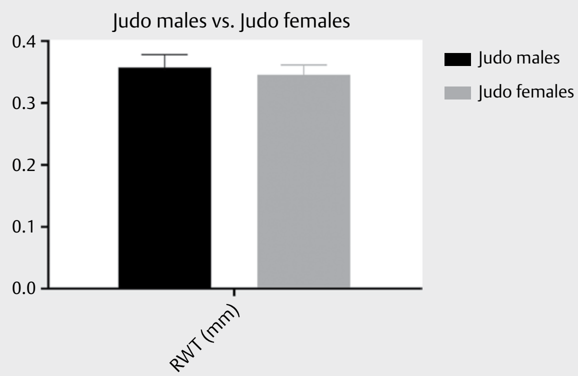
The analysis found statistically significant differences for IVSd (98.4 ± 10.6 mm vs. 82 ± 5.0 mm), PLWd (97.8 ± 8.9 mm vs. 84.7 ± 6.3 mm), LVM (233.44 ± 68.75 g vs. 164.11 ± 16.59 g), and LVMI (105.16 ± 24.89 vs. 84.66 ± 15.06) in male judokas (▶ **Fig. 2**). However, no significant difference in RWT was observed between male and female athletes (▶ **Fig. 3**) (▶ **Table 2**).

Discussion

In our study, significant differences in heart geometry remodeling between male and female judokas were demonstrated. As expected, significantly greater LV changes were observed in male compared to female athletes. The literature has already established that judokas, regardless of gender, have a significantly higher RWT and greater left ventricular mass than non-athletes of the same gender



▶ **Fig. 2** Male judokas vs female judokas – LVM, LVMI. Legend: LVM – Left ventricular mass; LVMI – Left ventricular mass index.



▶ **Fig. 3** Male judoka vs. female judoka – RWT. Legend: RWT – Relative wall thickness relative to the wall of the left ventricle.

▶ **Table 2** Cardiac geometry parameters of judo athletes.

Parameters	Males (n = 10)	Females (n = 9)	p value
	Mean ± SD	Mean ± SD	
IVSd (mm)	98.4 ± 10.6	82 ± 5.0	**0.002** ***
PLWd (mm)	97.8 ± 8.9	84.7 ± 6.3	**0.002** ***
RWT mm	0.35 ± 0.02	0.34 ± 0.01	0.167
LVM (g)	233.44 ± 68.75	164.11 ± 16.59	**0.009** ***
LVMI	105.16 ± 24.89	84.66 ± 15.06	**0.044** *

Legend: n – number of participants; SD – Standard Deviation; IVSd – Thickness of the interventricular septum in diastole; PLWd – Posterior ventricular wall thickness in diastole; RWT – Relative wall thickness; LVM – Left ventricular mass; LVMI – Left ventricular mass index; p value – statistical significance; *** – p < 0.01; * – p < 0.05.

[17], however the cardiac remodeling is complex and depends on various factors [18]. The results obtained are in line with research conducted to date, which indicate that gender is a significant factor that has an important influence on the change of heart geometry in athletes [19, 20]. Whyte et al. [21] conducted a survey of judokas, including 17 male and 14 female athletes, and 11 participants in the control group. The authors reported significantly higher RWT values in judokas than in the control group. RWT was also compared between male and female judokas, whereas significantly higher values were reported in favor of males. The results are related to the results obtained in our work [21].

A study of a total of 1083 combat sports athletes (males, n = 639; females, n = 444), found significantly lower LVM and RWT values in females than in male athletes, which matches our findings [10]. Furthermore, our data is inconsistent with previous research from 2021, conducted on a sample of 200 men and 78 women in weightlifting and various martial arts, which showed that female athletes were significantly more likely to have an eccentric type of hypertrophy than men who were more likely to have concentric remodeling of the LV [19]. The adaptations involve the entire cardiovascular system, particularly in athletes, LV root remodeling can also be expected due to the hemodynamic load caused by intensive training [22]. Although an increase in LV size has been observed in athletes in the past, as we demonstrated in our study, there is a limited amount of data in the literature on this type of remodeling [23]. Cardiac muscle adaptation in athletes involves a change in the entire cardiovascular system. A study was performed on the diameter of the LV, whereas a 13 % increase was observed in athletes compared to the control group [24]. In a sample of 2317 athletes, including 1300 males and 1017 females, a significant increase in aortic root size was found [23].

All these changes in LV geometry occur due to many factors, such as age, race, gender, and type of sport. Additionally, hormones are also assumed to have a major influence on cardiac remodeling in athletes, particularly sex hormones such as testosterone [25].

It is important to differentiate the athlete's heart and structural heart disease in youth [26]. The diagnostic doubt arises when the remodeling adaptations of the athlete's heart mimic some pathological conditions, such as hypertrophic and dilated cardiomyopathies [14]. There is currently little evidence regarding cardiac adaptation to resistance training in women. However, one study suggests that elite and highly trained female judokas show significant changes in the morphology of the LV [18]. A cross-sectional report revealed that 24 female weightlifters demonstrated concentric enlargement of the LV [27]. Considering that the athlete is often subjected to rapid weight loss [28–30] we can also raise a question whether this rapid and sudden weight loss before a competition can influence the athlete's cardiac remodeling? However, there is still no evidence in the literature on this.

The limitation of this study is the number of participants, future studies on the topic with a larger sample of athletes should be carried out. However, echocardiographic measurement depends on the operator, image quality, interobserver variability etc.

These results are also associated with the findings of Milovancev et al. (2021) according to which the physiological model of an athlete's cardiac adaptation is complex and varies according to the sport, therefore it must be specified for each sport discipline [31]. It probably depends on numerous individual parameters such as individual sport type, duration of practice, weekly training volume, athlete's weight category and other variables that influence the physiology of cardiac adaptation. The literature needs further studies to better clarify these complex aspects.

Conclusion

Comparison of male versus female heart muscle characteristics, as expected, showed both higher LVM (albeit still in the physiological range) and higher LVMI in males compared to female athletes. Based on the obtained results, we can define that LVM is mildly elevated for males and females, while as regards LVMI, results reported were within the normal range. Physiological cardiac enlargement in elite level judokas is an event that can likely occur but still needs further study and clarification. In fact, males do have larger heart muscle than females.

Conflict of Interest

The authors declare that they have no conflict of interest.

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