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ORIGINAL ARTICLE

Effects of taekwondo style practice on cardiac remodeling and isokinetic thigh strength in elite women players

Effets de la pratique d'un style de taekwondo sur le remodelage cardiaque et la force musculaire isocinétique des jambes chez des taekwondoïstes femelles élites

N. Hammami[a,*], B. Frih[b], H. Rahali[a], W. Mkacher[c], T. Rezgui[d], D. Čular[e], A. Bouassida[a]

[a] *Sport Sciences, Health & Movement (2SHM) Laboratory, High Institute of Sport and Physical Education of Kef, University of Jendouba, University campus of Boulifa, 7100 Le Kef, Tunisia*
[b] *Department of Biochemistry, Human Nutrition and Metabolic disorders, Functional Foods and Vascular Health (LR12ES05), Faculty of Medicine of Monastir, Monastir, Tunisia*
[c] *Department of Physiology and Lung Function Testing, Faculty of Medicine Ibn-El-Jazzar, University of Sousse, Sousse, Tunisia*
[d] *Applied Mechanics and Systems Research Laboratory (LASMAP), Tunisia Polytechnic School, University of Carthage, Tunis, Tunisia*
[e] *Croatian Institute of Kinesiology and Sport, Laboratory of Applied Physiology, Sport Systems, Talents Development and Influence of Physical Activities on Health, University of Split, Faculty of kinesiology, Split, Croatia*

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KEYWORDS
Leg force;
Echocardiography;
Heart;
Isokinetic;
Combat sport

Summary
Objectives. — Leg muscle strength estimation and cardiac functional exploration helps to better understand some physical demands of practicing different styles of Taekwondo. The current study aimed to demonstrate the effect of the two existing Taekwondo practices on cardiac remodeling and leg isokinetic muscle strength in female players.

* Auteur correspondant.
E-mail address: nedhirhammami@gmail.com (N. Hammami).

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Equipment and methods. — Twenty female taekwondo players divided into 2 groups [International Taekwondo (ITF) style ($n = 10$) and World Taekwondo (WT) style ($n = 10$)] were asked to achieve an echocardiographic exploration and concentric isokinetic evaluation of the knee at 60°/s and 180°/s with isokinetic dynamometer. Peak torqueses, peak torque relative to body mass, power and flexors/extensors ratios were studied.
Results. — ITF group presented almost a higher muscular strength of the two extensors and flexors compared to WT group at the two velocities ($P < 0.05$). There were no significant differences between dominant and non-dominant side for WT female. At 60°/s, ITF knee peak torque extensors (+18.8 Nm, ES = 0.5) and flexors (+ 32.73 Nm, ES = 0.95) were significantly higher than WT group ($P < 0.05$). Knee mean power flexors and extensors, peak torqueses flexors and ratio were greater also at 180°/s ($P < 0.05$). Echocardiography test showed the interventricular septum thickness (+ 1.12 mm, ES = 1.05), the shortening fraction (+ 5.13%, ES = 0.99) and the ''A'' wave velocity in Doppler echocardiography (+ 0.12 cm/s, ES = 1.62) were higher in the IT group compared to the WT group ($P < 0.05$). Since this study showed that IT females are stronger in their legs, and induce a better adaptation of left ventricle, they may be exposed to a serious risk of muscle and knee joints injuries.

MOTS CLÉS
Force des jambes ;
Échocardiographie ;
Cœur ;
Isocinétisme ;
Sport de combat

Résumé
Objectif. — L'estimation de la force musculaire des jambes et l'exploration fonctionnelle cardiaque aident à mieux comprendre certaines exigences physiques liées à la pratique de différents styles de Taekwondo. La présente étude visait à démontrer les effets des deux pratiques de Taekwondo existantes sur le remodelage cardiaque et la force musculaire isocinétique des jambes chez des femelles taekwondoïstes.
Matériel et méthodes. — Vingt joueuses de taekwondo réparties en 2 groupes (style international de taekwondo [ITF] [$n = 10$] et style mondial de taekwondo [WT] [$n = 10$]) ont été invitées à réaliser une exploration échocardiographique et une évaluation isocinétique concentrique du genou à 60°/s et 180°/s avec un dynamomètre isocinétique. Les moments de force maximaux, les moments de force maximaux rapportés à la masse corporelle, la puissance et les rapports fléchisseurs/extenseurs ont été étudiés.
Résultats. — Le groupe ITF a présenté une force musculaire presque plus élevée des deux extenseurs et fléchisseurs par rapport au groupe WT aux deux vitesses ($p < 0{,}05$). Il n'y avait aucune différence significative entre le côté dominant et le côté non dominant pour pratiquantes de WT. À 60°/s, les moments de force maximaux des extenseurs et des fléchisseurs du genou du groupe ITF étaient significativement plus élevés que ceux du groupe WT ($p < 0{,}05$). La puissance moyenne des fléchisseurs et extenseurs, les moments de force maximaux des fléchissurs et le rapport IJ/Q était également plus élevé à 180°/s ($p < 0{,}05$). Le test d'échocardiographie a montré l'épaisseur du septum interventriculaire (+1,12 mm, ES = 1,05), la fraction de raccourcissement (+ 5,13 %, ES = 0,99) et la vitesse de l'onde «A» en échocardiographie Doppler (+0,12 cm/s, ES = 1,62) étaient plus élevés dans le groupe IT que dans le groupe WT ($p < 0{,}05$). Les pratiquantes du IT sont plus fortes dans leurs jambes et induisent une meilleure adaptation du ventricule gauche, mais elles sont exposées à un risque sérieux de blessures aux muscles et articulations du genou.

Introduction

Taekwondo (TKD) training is generally based on movement, displacements, jumping, and kicks and punches in bags, pads and rackets. It includes classic and varied strengthening exercises [1]. In recent years, studies have analyzed the characteristics of leg muscle strength in TKD for performance optimization, in order to understand the physiological mechanisms underlying the production of different types of muscle strength (Maximum strength, Power, etc.) during training and competitions [2—5]. Worldwide, TKD is presented in two official forms. The traditional form of TKD is named ''ITF'' according to the ''International Taekwondo Federation'' and the other is governed by the ''World Taekwondo Organization'' (WT) also known as (WT) according ''World Taekwondo Federation. The WT style is more developed with 209 national associations' members [6]. Taekwondo as sport is included in Olympic Games competition program since 2000 [2]. However, the ITF form of TKD remains practiced around the world but has never achieved the success of its modernized WT rival [7].

The physical demands of competitive TKD induce a specific physical nature in the practitioner [2]. Indeed, competitive TKD in both forms is a dynamic sport where practitioners move with high speed and induce different powerful punches and kicks [7,8]. During a TKD fight, the taekwondo player makes a combination of these moves to score points [9]. Thus, training in TKD (ITF and WT) is based essentially on the development of speed and power qualities, but also on muscular strength (in order to be able to move body mass efficiently), flexibility (which will be necessary during the execution of the leg technical gesture) and endurance (ability to withstand fatigue during rounds in several fights) [3,7]. However, there is a lack of studies detailing the sessions training composition for both styles apart from the courses offered by the World Taekwondo Academy (WTA) for WT style [10] and International Taekwondo Federation (ITF) for ITF style [11]. Furthermore, the TKD Olympic elite favor kicks to score points at 98 to 100% of the time in competitions. The force developed by the lower limbs muscles seems to be one of the important factors for success [12]. Otherwise, the muscle strength developed by the ''WT'' players legs is considerably higher compared to that developed in the ''ITF'' players [13]. This physical quality is a crucial element of the sport form in combat sport [14] and more particularly in TKD of ITF [15] and WT [16].

In the TKD, the dynamic force developed by the muscles and associated with the segmental speed of execution, would allow a powerful, effective and efficient strike [2]. A very fast movement is triggered by a strong contraction that launches the segment in action [17]. Thereby, the evaluation and balanced development of synergistic muscles compared to the antagonistic muscles seems very important for the practice of TKD [1]. Indeed, the determination of isokinetic strength is a method of measuring the tension exerted on the muscle tissue while moving regularly at a given angular velocity [18,19], especially since isokinetic activity allows athletes to determine strength profiles according to the practiced discipline and the nature of the training [2,3,20]. In the scientific literature, few studies have examined the isokinetic exploration of muscle strength in ''ITF'' players. Pędzich et al. [13] showed the supremacy of forces developed by the lower limbs muscles of male ''WT'' players compared to ''ITF'' players and boxers, following isokinetic muscle assessment of the elbow, shoulder, hip, knee and ankle joints. In addition, studies on isokinetic dynamometric muscle exploration are also relatively absent in female ITF players with the exception of the study of Szafrański & Boguszewski in 2015 [21].

In another context, ITF taekwondo practice involves physiological changes and training adaptations that partly affect the heart [7]. This is an improvement in cardiovascular capacity gained through suitable physical exercise. Because of training, the hearts of athletes can undergo significant structural and electrical changes; which represents a particular challenge for the cardiovascular specialist. It is important to understand normal adaptive changes in order to separate normal physiology from pathology [22—24]. Researchers have recently shown that intense and prolonged physical training leads to adequate, targeted and high-performance cardiovascular adaptations [25—28]. These adaptations usually incorporate functional and anatomical changes to the heart, often referred to as ''Cardiac Remodeling''.

Clinically, cardiac remodeling is a change in the heart size, shape and function caused by a cardiac anomaly or potentially, by the different types of physical efforts and sport training. Several studies have focused on the type of cardiac change where its adaptation may be peripheral (hypertrophy) or central in the ventricular walls (especially of the left ventricle) [29—32]. Other studies have shown that cardiac remodeling observed in a high-level athlete is often directly related to the type of sport practiced and the intensity of the training [30,33]. For a regular practice of TKD exceeding 20 minutes per session, cardiovascular changes were recorded in both sexes regardless of their level of practice [34]. The TKD, in its two forms ITF and WT, is considered as dynamic and intense combat sport that requires certain demands on the led muscular power as well as on the cardiovascular adaptation to the effort. To our knowledge, the scientific literature has not addressed which of either TKD forms would have more impact on these parameters for female practitioners.

This study aimed to show the effect of two TKD styles (ITF and WT) practice on cardiac remodeling and isokinetic muscle strength of the lower limbs in elite female taekwondo players.

Methods

Participants

The study included 20 Tunisian female TKD players. They were in good health with no pathological history for at least one year before the experiments, and belong to the expanded list of the Tunisian Regional Female's Team (Northwestern sector) under the auspices of the Tunisian Taekwondo Federation. Participants were divided into two groups, one is an ITF Group (ITF, $n = 10$) and the other is a WT group (WT, $n = 10$). The inclusion criteria were:

- 1st DAN Black Belt holder or more;
- age between 18 and 23 years old;
- national team member more than one year.

All participants have signed a written consent to participate in the study after passing through medical check-up by a cardiologist and a sports physician jointly. The experiment was performed according to the Ethics Committee instructions of the university, following the guidelines of the Helsinki Declaration for the treatment of natural persons during scientific research, and the recommendations of the US National Institute of Health through the module of ''Protecting Human Research'' Participants ''(PHRP—NIH, USA).

Measures

To perform the isokinetic tests, a BIODEX® isokinetic dynamometer appointed ''Biodex System 3Pro (#830—520)'' was used with an onboard computer that controls its operation through specific software ''Biodex'' ensuring the passing of tests. A range of accessories is available to test all major joints of the human body including the knee. The isokinetic parameters selected were peak torque (Nm), peak torque relative to body mass (Nm/kg) and mean power (w) in both, the dominant and non-dominant limbs. The Flexion/Extension (F/E) ratio (Hamstrings/Quadriceps) was also calculated and the concentric contraction mode was chosen for each angular speed [1,35].

Echocardiographic measures were conducted using ''GE Brand Logiq 500 pro'' device. In the subject at rest, a study in Time Motion (TM) and Two-dimensional (TD) mode was made to determine the Septal Thickness (ST) and the Posterior Wall (PW), Left Ventricular End-Diastolic Diameter (LVEDD), Left Ventricular End-Systolic Diameter (LVESD) on the recommendations of the American Society of Echocardiography. On the Left Atrium (LA), the surface section in apical four cavities, and the cross-sectional diameter in TM mode in cross-sectional major axis have been calculated. Other parameters were measured: The LV Fractional Shortening (FS), the Ejection Fraction (EF) of LV in Simpson Biplane, the Diameters of the Mitral and Tricuspid Rings (MRD, TRD) in apical section four cavities, the Right Atrium (RA) surface and the End-Diastolic Diameter of the RV (RVEDD) in cross section and its length in apical section. LV mass was calculated according to the PENN convention [36]. In addition, measurement of the transmitral filling flow was obtained by pulsed Doppler in four-cavity apical section by positioning the Doppler sample at the top of the mitral funnel. The E-Wave Velocity (EWV), the A-Wave Velocity (AWV), the Deceleration Time (DT) of the E-Wave, the Ejection Time (ET), the Pressure Half Time (PHT) and the Isovolumetric Relaxation Time (IVRT) are systematically calculated [37]. To ensure repeatability and precision, all echocardiographic measurements were made by the same physician.

Design and Procedures

The tests were conducted in accordance with the required conditions during isokinetic evaluations validated by the scientific literature [38] in the specific preparation period of the 2018-2019 sports season. Participants were warned clearly and precisely about all the test steps procedure with the use of the safety system in case of accident. A 10-minutes warm-up was required on a medium-speed ergometer followed by some legs joint mobilization and stretching exercises. After that, the participant was placed on the chair with a 15° trunk inclination relative to the vertical axis. The trunk, pelvis and thigh of the member tested were strapped and the corresponding accessory was hooked on the knee. Moreover, the knee flexion-extension range of motion (ROM) was identified following the manufacturer's recommendations for knee assessment. Few trials (3 submaximal and 2 maximum isokinetic concentric contractions) at 60°/s and 180°/s angular velocities were conducted in order to allow an optimal familiarization with the test with 5 minutes of rest between trials [39]. For each speed, measurements are conducted for both legs, five times while keeping the contralateral limb and ankle of the tested side free [40]. After finishing with one leg, move to the other leg. The recovery time between each angular velocity tested was estimated at 3 minutes. To motivate participants, verbal encouragements were made. Gravity was taken into account in the protocol and assessments.

Echocardiographic measurements were taken 48 hours after isokinetic tests for four days, at a rate of five participants per day.

Table 1 Main characteristics of the participants in the study (*N* = 20).

	ITF (*n* = 10)	WT (*n* = 10)
Age (years)	19.20 ± 1.22	19.50 ± 1.35
Body mass (Kg)	65.50 ± 2.41	64.30 ± 1.82
Body height (cm)	164.6 ± 4.37	164.1 ± 5.04
Fat (%)	19.26 ± 3.47	19.22 ± 4.23
Training time/Week (h)	15—17 h	16 h
Training experience (years)	4.9 ± 4.04	6.3 ± 1.76

Statistical Analysis

The statistical study was carried out by the software ''STATISTICA 11.0 (Tulsa, OK, USA'' for Windows). The results are reported in mean values ± standard deviation. The study of the normality of the distribution was evaluated with the ''Kolmogorov-Smirnov'' test to define the choice of the use of tests (parametric or non-parametric). Data were analyzed using a two-way analysis of variance (group (WT and ITF) × leg (Dominant and Non-dominant)) for isokinetic parameters comparisons. Bonferroni was used as post hoc test. The *t*-test for independent samples was used for the cardiac remodeling. The effect size (ES) was calculated through Cohen's ''*d*''. Statistical significance was set at $P < 0.05$.

Results

The main characteristics of the participants in the study were presented in the Table 1.

Differences between groups and dominant and non-dominant leg for each group are presented in Table 2. Compared to the WT group, ITF group exhibited very significantly a great legs extensors PT ($F_{1,36} = 40.2$; $\eta^2 = 0.52$; $P = 0.00000$) and PTbm ($F_{1,36} = 41.37$; $\eta^2 = 0.53$; $p = 0.00000$) at 60°/s. The legs flexors were stronger among ITF group [PT ($F_{1,36} = 7.05$; $\eta^2 = 0.16$; $P = 0.011$) and PTbm ($F_{1,36} = 6.05$; $\eta^2 = 0.14$; $P = 0.018$)] at the same angular speed. In addition, no significant differences were found in comparison between Dominant and Non-dominant side for all groups at 60°/s ($P < 0.05$). Moreover, an interaction effect was found between legs (Dominant and Non-dominant sides) and group factors ($F_{1,36} = 8.23$; $\eta^2 = 0.18$; $P = 0.0068$) with higher values for PT and PTbm Flexors of ITF dominant leg in comparison to Non-dominant leg (respectively $P = 0.049$ and $P = 0.04$) and in comparison to WT dominant one (respectively $P = 0.002$ and $P = 0.003$).

For the 180°/s speed, the extensors' MP of ITF group were higher than WT group ($F_{1,36} = 8.56$; $\eta^2 = 0.19$; $P = 0.0059$) as well as the flexors PT ($F_{1,36} = 7.05$; $\eta^2 = 0.16$; $P = 0.011$), PTbm ($F_{1,36} = 5.66$; $\eta^2 = 0.13$; $P = 0.022$), MP ($F_{1,36} = 5.88$; $\eta^2 = 0.14$; $P = 0.02$) and the legs ratio ($F_{1,36} = 9.24$; $\eta^2 = 0.2$; $P = 0.0004$). However, an interaction effect was found between legs (Dominant and Non-dominant sides) and group factors ($F_{1,36} = 4.58$; $\eta^2 = 0.11$; $P = 0.03$) with higher ratio of ITF dominant side in comparison to WTF dominant side ($P = 0.004$)

Table 3 shows the analysis of the echocardiographic and Doppler parameters performed for the WT and ITF

Table 2 Lower limbs Isokinetic parameters (Mean ± SD) of elite female Taekwondo players.

			WT (*n* = 10)			ITF (*n* = 10)		
			Dominant	Non-dominant	Overall	Dominant	Non-dominant	Overall
60°/s	Extension	PT (Nm)	156.93 ± 14.62	152.66 ± 16.04	154.79 ± 15.1	207.65 ± 24.8	188.85 ± 28.11	198.25 ± 27.56[a]
		PTbm (Nm/kg)	2.44 ± 0.2	2.37 ± 0.21	2.4 ± 0.2	3.16 ± 0.33	2.88 ± 0.41	3.02 ± 0.39[a]
		MP (W)	123.21 ± 29.85	126.67 ± 34.1	124.94 ± 31.24	140.73 ± 31.58	137.25 ± 36.79	138.99 ± 33.42
	Flexion	PT (Nm)	97.67 ± 14.62	112.4 ± 29.82	105.03 ± 28.11	143.91 ± 24.62[b,c]	111.18 ± 24.09	127.54 ± 29.05[a]
		PTbm (Nm/kg)	1.52 ± 0.40	1.75 ± 0.48	1.63 ± 044	2.19 ± 0.35[b,c]	1.69 ± 0.33	1.94 ± 0.42[a]
		MP (W)	121.18 ± 39.86	130.26 ± 37.89	125.72 ± 43.35	142.68 ± 45.31	147.92 ± 47.73	145.3 ± 45.37
		Ratio	0.63 ± 0.19	0.74 ± 0.24	0.68 ± 0.22	0.7 ± 0.13	0.59 ± 0.11	0.64 ± 0.13
180°/s	Extension	PT (Nm)	148.19 ± 30.24	131.9 ± 23.39	140 ± 27.61	132.35 ± 23.3	150.98 ± 39.54	141.66 ± 33
		PTbm (Nm/kg)	2.31 ± 0.5	2.16 ± 0.49	2.23 ± 0.49	2.01 ± 0.31	2.29 ± 0.54	2.15 ± 0.45
		MP (W)	197.74 ± 19.28	205.75 ± 47.13	201.74 ± 35.29	254.31 ± 69.73	251.86 ± 69.68	253.08 ± 67.86[a]
	Flexion	PT (Nm)	85.49 ± 19.65	85.26 ± 15.03	85.37 ± 17.02	110.45 ± 30.08	101.5 ± 29.79	105.97 ± 29.49[a]
		PTbm (Nm/kg)	1.33 ± 0.31	1.32 ± 0.24	1.33 ± 0.27	1.68 ± 0.47	1.54 ± 0.44	1.61 ± 0.45[a]
		MP (W)	126.21 ± 42.54	145.33 ± 31.39	135.77 ± 37.68	169.81 ± 60.32	176.84 ± 56.07	173.32 ± 56.79[a]
		Ratio	0.58 ± 0.11	0.62 ± 0.1	0.6 ± 0.11	0.83 ± 0.25[b]	0.67 ± 0.13	0.76 ± 0.21[a]

PT: Peak torque; PTbm: Peak torque relative to body mass; PM: Mean power; Ratio: Ratio knee flexors/extensors (H/Q).
[a] Significant difference between WT and ITF ($P < 0.05$).
[b] Different from WT Dominant leg ($P < 0.01$).
[c] Different from ITF Non-dominant leg ($P < 0.05$).

Table 3 Echocardiographic and Doppler parameters (Mean ± SD) of elite female Taekwondo players.

	WT	ITF
	TM and TD modes	
Aorta (mm)	23,82 ± 2,24	24,30 ± 2,78
LA (mm)	33,86 ± 5,16	34,95 ± 4,15
IST (mm)	7,07 ± 0,62	8,19 ± 1,37[a]
PWIVS (mm)	6,85 ± 0,62	7,43 ± 0,74
RVEDD (mm)	48,94 ± 4,35	47,59 ± 2,86
RVESD (mm)	28,38 ± 3,39	30,00 ± 2,07
SF (%)	37,74 ± 3,73	42,87 ± 6,23[a]
LVEDD (ml)	124,63 ± 32,70	117,76 ± 9,65
LVESD (ml)	51,55 ± 12,29	50,57 ± 10,26
EFLV (%)	59,33 ± 7,23	63,06 ± 7,40
RAA (cm^2)	13,36 ± 2,65	13,10 ± 0,94
LAA (cm^2)	15,78 ± 2,80	16,40 ± 2,27
TRD (mm)	32,16 ± 4,29	33,03 ± 2,78
RVL (mm)	65,35 ± 8,51	64,37 ± 3,44
	Doppler	
EWV (cm/s)	1,07 ± 0,10	1,16 ± 0,18
AWV (cm/s)	0,50 ± 0,053	0,62 ± 0,09[a]
IVRT (ms)	60,92 ± 11,63	59,41 ± 6,8
TEmit (ms)	310,70 ± 62,80	331,30 ± 35,03
PHT (ms)	73,78 ± 12,52	80,75 ± 11,32

TD: Two-dimensional; TM: Time Motion; LA: Left Atrium; IST: Interventricular Septum Thickness; PWIVS: Posterior Wall Interventricular Septum; RVEDD: Right Ventricular End-Diastolic Diameter; RVESD: Right Ventricular End-Systolic Diameter; SF: Fractional Shortening; LVEDD: Left Ventricular End-Diastolic Diameter; LVESD: Left Ventricular End-Systolic Diameter; EFLV: Ejection Fraction of Left Ventricular; RAA: Right Atrium Area; LAA: Left Atrium Area; TRD: Tricuspid Ring Diameter; RVL: Right Ventricular Length; EWV: E-Wave Velocity; AWV: A-Wave Velocity; IVRT: Isovolumetric Relaxation Time; TEmit: Time of mitral E-wave; PHT: Pressure Half Time
[a] Significant difference between WT and ITF ($P < 0.05$).

groups. No significant differences were found between the two groups for most parameters ($P < 0.05$). Only the interventricular septum thickness (IST) (8.19 ± 1.37 mm vs. 7.07 ± 0.62 mm, ES = 1.05), the shortening fraction (SF) (42.87 ± 6.23% vs. 37.74 ± 3.73%, ES = 0.99) and the A wave velocity in Doppler echocardiography (0.62 ± 0.09 cm/s vs. 0.50 ± 0.053 cm/s, ES = 1.62) were higher in the ITF group compared to the WT group ($P < 0.05$).

Discussion

The objective of the study is to show the impact of two different styles (WT vs. ITF) in TKD practice on heart adaptation, through cardiac remodeling, and on the isokinetic muscle strength of the thigh among elite female TKD players. It would try to reveal the effect of training induced in TKD through its two styles on cardiac and muscular level in order to propose intervention strategies in the field and how to correct the content of training sessions.

The main findings indicated a considerable high PT extensors and flexors legs for ITF female at slow angular speed (Table 2). Although ITF and WT groups members belonged to the same weight category (−67 kg to −69 kg), the values show that ITF female sample develop more muscle strength of the quadriceps. The physical fitness training of ITF group seems to be the cause of this observation. Training is therefore based in most sessions on exercises and leg movements that support the body mass continuously and repetitively [41]. Unlike WT style, the attack techniques are distributed almost equally between upper limbs (punches) and lower limbs (kicks) in ITF style [13,42] and most of training sessions are led by muscle strengthening exercises of legs, mainly for extensors and flexors [11]. This result corroborates the regular presence of strength exercises in training programs of ITF group and leads us to believe that WT group's training sessions include little or not enough muscular strengthening. Furthermore, ITF group dominant side is significantly higher for PT and PTbm flexors compared to those of WT group ($P < 0.05$) which could give one more index on the distribution and integration of muscle strengthening training amongst ITF women. Controversially, the literature findings have found the opposite results [13]. Also, Hammami et al. [2] stated that a strength training program induces similar PT values in practitioners despite their weight class and near the general preparation phase at the beginning of the sports season. The body responses to the muscular strength training solicitation combined with that of power are not different between players when evaluated on 60°/s [1].

At 180°/s speed, legs extensors muscular power, flexors PT and PTbm as well as ratio are more developed in ITF female than WT ($P < 0.05$). Interestingly, this result was a bit surprising although expected by referring to the results of slow speed and to the content of training sessions. The both styles require muscular power and strength to effectively perform and support different actions in competition and training [3,43,44]. The WT group training is based on aerobic power, speed, agility and flexibility with technical and tactical work, where club coaches rarely include full and balanced muscular strength sessions, and simply perform plyometric exercises at the end of the warm-up or the session, referring to the typical training learned by the old TKD founders. In the literature, continuous training using elastic bands with different elasticity and varying according to each TKD strike techniques may contribute to increase the impact force during TKD matches [45]. In our case, the ITF sample persevered to train with the elastic bands during the general and specific physical preparation phases contrary to WT style where the physical trainer denied the use of such material. This could be part of the result explanation.

Otherwise, the dominant knee ratio (flexors/extensors) was higher for ITF group at 180°/s providing important information about knee joint stability and confirming a better muscle and joint balance on this side. However, this is not the case in the non-dominant side. Its ratio was very lower through the comparison between the two legs (Table 2). Obviously, their non-dominant hamstrings and quadriceps presented a worrying weakness when the Ratio was under 0.75. Values below this threshold are correlated to greater incidence of lower extremity injury for young female [46]. This could be explained by a potential disproportion in muscular strength work in each side especially that TKD females did not raise knee ratio by increasing the angular velocities [46] and may be related to the development of neuromuscular imbalances associated with the onset on maturation [46,47]. Moreover, the comparison between the two sides at 60°/s showed a significant difference ($P < 0.05$) on PT and PTbm for the ITF group. The non-dominant muscle thigh developed less strength for the same technical actions performed by the leg which can cause lower limbs imbalance and instability, most often followed by the anterior cruciate ligament or menisci rupture [46,48—50]. Training modalities, exercise choices and judicious distribution of training loads between the legs, especially during combined technical work, seem the cause of this finding. Coaches do not pay attention to foster one side over the other, nor a muscle group (agonist) despite the other group (antagonist).

In another context, heart parietal hypertrophy is still a subject of study in sports cardiology, [51—53]. Generally, the LV walls thickness is moderately increased, but the IST remains in most cases less than 12 mm [54,55]. The available data are few in some populations (female's series, adolescents), which makes it possible to propose unambiguous threshold values. In female, in the light of a series of 600 highly trained and competitive female and involved in various sports, the value of 12 mm has never been exceeded [33,56]. A meta-analysis of Pluim et al. [57] confirmed that the increase in wall thickness was lower in endurance athletes with a heart eccentric geometry compared to resistive athletes (in isotonic disciplines) having rather a concentric geometry. This finding was resumed in recent study [58]. Moreover, the average thickness of IST in ITF was higher compared to WT group ($P < 0.05$). SF was elevated in the same group with poorer systolic function (in addition to EFLV analysis). In the literature, a percentage of SF less than 29% indicates a functional heart disease [59,60], but smaller it is (not exceeding 29%), better is the LV systolic function. The ITF style seems to induce a better LV remodeling compared to the WT style.

Otherwise, the study of LV filling through the transmitral flow indicated higher ''A'' wave values in the ITF group. Individually, the transmitral flow of the athlete is sometimes restrictive, but the ''A'' wave is always linked to the ''E'' wave thus determining the quality of the contraction of the Left Atrium [26]. The collection of the pulsed tissue Doppler traced to the mitral ring confirms the normality of the situation by showing a large ''E'' wave. For the TKD female, despite the difference in the values of the ''A'' wave, the population seems healthy heaving a Left Atrium normal functioning and approaching the threshold values of the athletes identified in literature review [61—63].

Through this study, a comparative profile of isokinetic muscle strength in concentric mode of knee flexors and extensors was established for the two styles of Taekwondo (WT and ITF) among female practitioners. However, the eccentric isokinetic strength has not been evaluated. Additional tests in eccentric mode and faster speed tests as well as mixed evaluations (concentric quadriceps muscle/eccentric hamstring ratios) would be necessary in order to better prevent muscular and joints risks of injury. Moreover, additional measures by right ventricle echocardiography should be added to predict optimal reshaping of the functioning of the heart in this population. Moreover, additional echocardiography measurements of RV should be added to predict optimal remodeling of heart function in this population.

Conclusion

The thigh muscular strength of the preferred leg was more developed in the ITF female with a clear imbalance in the non-dominated leg especially at the 60°/s speed. Furthermore, the ITF style seems to induce a better adaptation of the left ventricular compared to the WT style among practicing females. Larger studies focusing on the RV, with the larger numbers are needed to get a complete and expressive profile of cardiac remodeling in high-level women TKD players. In addition, the practice of TKD in all its known forms induces positive effects on muscle strength and cardiac adaptations to exercise. The differences in the two styles techniques are not significant, but the training contents and the physical load seem to cause problems of stability and balance of lowers extremities at ITF female. Coaches and physical trainers are advised to design more adequate programs in term of personalized and specific muscular strengthening.

Disclosure of interest

The authors declare that they have no competing interest.

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