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The effects of different physical activities on atrial fibrillation in patients with hypertension and chronic kidney disease

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Background: Atrial fibrillation (AF) is highly common, and is most frequently observed in individuals with hypertension and structural cardiac disease. Sympathetic hyperactivity plays a fundamental role in the progression, maintenance and aggravation of arrhythmia. Endurance exercise training clearly lowers sympathetic activity in sympathoexcitatory disease states, and is well-tolerated by patients with chronic kidney disease (CKD).
Methods: We assessed 50 CKD patients with hypertension. Each patient provided a complete medical history and underwent a physical examination. We used an implantable cardiac monitor over a 3-year follow-up period to evaluate the effects of high-intensity interval training (HIIT) and moderate exercise (ModEx) physical activity protocols on AF occurrence, and determined the effectiveness of these protocols in improving renal function. Subjects were followed up every 6 months after the beginning of the intervention.
Results: During the 3-year follow-up, AF onset was higher in CKD patients who engaged in HIIT (72%) than in those who engaged in ModEx (24%) (hazard ratio, 3.847; 95% confidence interval, 1.694–8.740, P = 0.0013 by log-rank test). Both groups exhibited significant intra-group changes in the mean systolic 24-hour ambulatory blood pressure measurements (ABPM) between baseline and 12, 24, and 36 months. There were also significant differences in the mean systolic 24-hour ABPM between the groups at the same time points.
Conclusion: In CKD patients with hypertension, improvements in AF onset, renal function and some echocardiographic parameters were more evident in subjects who engaged in ModEx than in those who engaged in HIIT during 3 years of follow-up.

Keywords: Atrial fibrillation, Chronic kidney disease, Exercise, Hypertension, Sympathetic hyperactivity

Introduction

Sympathetic hyperactivity plays a key role in the development, maintenance and aggravation of arrhythmias [1]. Recently, Howden et al [2] suggested that endurance training influences many factors that can reduce sympathetic activity. Endurance exercise training obviously lowers sympathetic activity in sympathoexcitatory disease states [3,4], and is well-tolerated by patients with chronic kidney disease (CKD) [5,6]. The effects of endurance training on renal sympathetic nerve activity have been measured

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in healthy adults [7], but not in individuals with CKD. Thus, proof-of-principle studies are required.

Physical activity has the profound benefits of lowering cardiovascular morbidity and mortality, and physical inactivity is a major risk factor for cardiovascular disease. The specific effects of physical activity on the development of atrial fibrillation (AF) are less well documented, and intervention studies [8–15] examining these effects are lacking. In the present study, we evaluated the effects of high-intensity interval training (HIIT) and moderate exercise (ModEx) on AF occurrence (using an implantable cardiac monitor) and renal function in patients with CKD over a 3-year follow-up period.

Methods

Definitions

Paroxysmal AF (PAF) was defined as AF episodes lasting < 7 days with spontaneous termination. Persistent AF (PersAF) was defined as AF lasting > 7 days before either pharmacological or electrical cardioversion intervention.

HIIT is a cardiovascular workout strategy in which individuals repetitively engage in a short burst of maximum-intensity exercise (anaerobic exercise), followed by short-term lower-intensity activity (recovery), until fatigued. HIIT can be defined as a session in which HIIT is either the only exercise or an element of an exercise regimen. HIIT implementation sessions usually comprise a warm-up period, several repetitions of high-intensity exercise interspersed with medium-intensity exercise for recovery, and then a cool-down period. The high-intensity exercise should be performed at nearly maximum intensity, while the medium-intensity exercise should be performed at approximately 50% intensity. The number of repetitions and the length of each interval are specific to the workout, but may be as low as three repetitions with only 20 seconds of extreme exercise [16]. The exact workouts performed during the high-intensity portions can vary, and the moderate-intensity segments can be as slow as walking, depending on subject's level of cardiovascular health [17]. A common formula involves a 2-to-1 ratio of effort-to-recovery stages; for example, 30–40 seconds of hard sprinting interspersed with 15–20 seconds of jogging/walking. There is no specific equation for HIIT, and there are no international guidelines for the HIIT session duration, but an entire HIIT session typically lasts between four and thirty minutes; thus, this regimen is an excellent method of maximizing a workout with limited time [18,19]. Usage of a timer is recommended to monitor the precise interval times, number of rounds, and intensity.

ModEx to engage in physical activity (starting with 150 minutes of moderate activity per week, as endorsed by the Brazilian Ministry of Health, and progressively increasing).

- During the first 6 months: 30 minutes of daily aerobic exercises five times per week, with a program including walking on a treadmill and cycling on a stationary or transport bicycle. Heart rate target: 55% of maximal heart rate.
- From months 6 to 12: 45 minutes of daily aerobic exercises five times per week, with a program including walking on a treadmill and cycling on a stationary or transport bicycle. Heart rate target: 65% of maximal heart rate.
- From months 12 to 18: 60 minutes of daily aerobic exercises five times per week, with a program including walking on a treadmill and cycling on a stationary or transport bicycle. Heart rate target: 75% of maximal heart rate.
- From month 19 onward: 60 minutes of daily aerobic exercises five times per week, with a program including walking on a treadmill and cycling on a stationary or transport bicycle. Heart rate target: 85% of maximal heart rate.

Study subjects

We conducted a prospective, longitudinal study in 50 sedentary patients with CKD and controlled hypertension. At baseline, all of them initiated a physical activity regimen. However, the patients were randomly divided 1:1, such that 25 patients started with an HIIT regimen, and the other 25 subjects engaged in a ModEx protocol. The study complied with the Declaration of Helsinki and was approved by the Ethics Committee of Hospital e Clínica São Gonçalo (No. HCSG2013001). All patients signed written informed consent before enrollment. In the present study, we aimed to evaluate the effects of exercise type performed in the context of AF occurrence (as measured by an implantable cardiac monitor), estimated glomerular filtration rate (eGFR) and the urinary albumin:creatinine ratio (ACR) in all patients.

This study was conducted at the Hospital e e Clínica São Gonçalo in the state of Rio de Janeiro, Brazil, in conjunction with CardioStim Arrhythmias and Artificial Cardiac Pacing Service Research. Subjects were recruited from our institutions between January and December 2013. Consecutive patients who met the following criteria were enrolled: (i) mean 24-hour systolic ambulatory blood pressure measurements (ABPM) < 130/< 180 mmHg; (ii) age between 18 and 75 years; (iii) structurally normal heart based on myocardial scintigraphy and transthoracic echocardiography; no ischemia, fibrotic region or any other illness; and a left ventricular (LV) ejection fraction of > 50%, as measured by echocardiography (Simpson's method); (iv) no history of symptoms such as dyspnea, palpitation, dizziness, pre-syncope, syncope or AF; (vi) provided permission to implant a cardiac monitor; (vii) a eGFR < 60 mL/min/1.73 m^2 as estimated by the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [20]; and (viii) capable of reading, comprehending and signing the written informed consent form.

The following exclusion criteria were applied: (i) pregnancy; (ii) valvular disease with significant hemodynamic repercussions; (iii) myocardial infarction, unstable angina, stroke or transient ischemic attack within the previous 6 months; (iv) mobility deficit; (v) psychiatric disease; (vi) inability to be clinically followed; (vii) known drug or alcohol addiction, which can affect the ability to understand or follow medical instructions; (viii) comorbidity with a serious disease that, in the opinion of the investigator, could have adversely affected the safety and/or efficacy of either the participant or the study; (ix) a eGFR < 15 mL/min/1.73 m^2, as estimated by the CKD-EPI equation [20].

Implantable cardiac monitor

The implantable cardiac monitor SJM Confirm™ (St. Jude Medical, St. Paul, Minnesota, USA) checks and diagnostically evaluates patients who experience unexplained indicators such as dizziness, palpitations, chest pain, syncope and shortness of breath, as well as subjects who are at increased risk for cardiac arrhythmias. Some prototypes also allow for the monitoring of patients previously diagnosed with or at risk of developing AF. This device enables the transmission of vital information through extensive data reporting. These reports include AF burden, episode duration, episode count, episode date/time stamp, heart rate histogram, and episodic diagnostics for an auto-triggering event. The device also allows for streamlined follow-up with the Merlin™ Patient Care System (St. Jude Medical), trans-telephonic monitoring, and timely and accurate transmission of data, all of which facilitate evaluation of the patient's condition. The SJM Confirm™ is small (6.5 mL) and has a three-year lifespan, sub-cutaneous electrodes for simplified implantation, and detectors to filter the noise response and activity response.

The subjects were placed in a dorsal decubitus position, sedated by an anesthesiologist and intravenously administered cefazolin (1 g). Local anesthesia was performed with 7.5% ropivacaine. Subsequently, a cutaneous incision was made in the left pectoral region, and dissection was conducted along the planes of the subcutaneous tissue transverse left to create a pectoral pocket. Then, the SJM Confirm™ was inserted. After the incisions were closed, a compressive dressing was placed on top of the wounds.

24-hour ABPM

ABPM was performed for 24 hours at baseline with a clinically valid device (CardioMapa; Cardios, São Paulo, Brazil). The device was set to measure every 15 minutes during the day (06:00 to 22:00) and every 30 minutes during sleep (22:00 to 06:00). Individuals were instructed to conduct their normal activities throughout the recording and to go to bed no later than 23:00. The waking time typically encompassed 08:00 to 22:00, and the sleep period included 00:00 to 06:00 [21]. All subjects were proficient in recording their sleeping and waking times, meals, intake of medications, and any warning signs or events that could have influenced blood pressure during this period in a journal. Measurements were transmitted to a computer for analysis. Monitoring was repeated as necessary until ≥ 70% of the measured values obtained during both the daytime and nighttime periods were satisfactory [22].

Transthoracic echocardiography

Transthoracic echocardiography was performed at baseline with a Vivid I ultrasound system (General Electric, Frankfurt, Germany) fitted with a multi-frequency transducer and tissue Doppler imaging software, in accordance with the guidelines of the American Society of Echocardiography [23]. Data were evaluated and interpreted by an experienced echocardiographer who was blinded to the treatment status and imaging sequence. The LV mass was quantified from the LV linear dimensions with the Devereux formula [23,24] and normalized to the body surface area (BSA) [23,25]. LV hypertrophy was considered present when the LV mass exceeded 115 g/m^2 for men and 95 g/m^2 for women [23]. The left atrial (LA) volume was measured with a disk sum algorithm similar to that used to measure the LV volume [26,27], and was normalized to the BSA. Although the LA size depends on sex, variation due to sex is generally considered when the values are normalized to the BSA [28]. Furthermore, although there are several methods of normalizing this measurement [29,30], normalizing to the BSA produces the most reliable data. Normalizing to the BSA compensates for sexual dimorphism in the LA size; thus, only the normalized value is reported. The recommended upper limit for LA size is 34 mL/m^2 [30–33].

Study procedures and assessment

We assessed 50 CKD patients with hypertension. Each patient provided a complete medical history and underwent a physical examination. We evaluated the effects of the HIIT and ModEx physical activity protocols on AF occurrence (as determined with the implantable cardiac monitor over a 3-year follow-up period) and renal function. Follow-up was performed every 6 months after the initiation of the exercise regimens.

Statistical analyses

The results are expressed as the mean and standard deviation for normally distributed data and as the median and interquartile range for non-normally distributed data. A paired *t*-test was used to compare paired values in cases of a Gaussian distribution; otherwise, the Wilcoxon test was used. The D'Agostino-Pearson test was used to determine the normality of the distribution. Comparisons among more than two values were made with either repeated-measures analysis of variance or Kruskal–Wallis analysis of variance as appropriate, and both assessments were complemented with the *post-hoc* Tukey test. Fisher's exact test was used to compare categorical variables. A two-tailed *P* value < 0.05 was used as the criterion for statistical significance. Kaplan–Meier analysis was performed to determine the probability of success and estimated as the percentage of AF freedom. Differences in arrhythmia-free survival were assessed with the log-rank test. Cox regression analysis was used to explore factors contributing to the recurrence of AF. All statistical analyses were performed with GraphPad Prism ver. 7.0 (GraphPad Software, La Jolla, CA, USA).

Results

Baseline characteristics of patients

The general features of the patient groups are listed in Table 1. The groups did not differ in any parameter besides age ($P = 0.0008$).

Table 1. General features of patients at baseline

Parameter	HIIT group	ModEx group	*P* value
Patient (n)	25	25	–
Age (yr)	52 ± 10	63 ± 9	0.001
Body mass index (kg/m^2)	25.8 ± 2.3	25.4 ± 1.9	0.487
Male gender	18 (72)	15 (60)	0.551
White ethnicity	18 (72)	13 (52)	0.244
Type 2 diabetes mellitus	6 (24)	8 (32)	0.754
Antihypertensive			
ACE-inhibitors/ARB	25 (100)	25 (100)	1.000
Diuretics	20 (100)	20 (100)	1.000
DHP Ca^{++} channel blockers	8 (32)	6 (24)	0.754
Clonidine	8 (32)	5 (20)	0.520
Echocardiographic parameters			
Indexed left atrial volume (mL/m^2)	30.5 ± 2.1	31.0 ± 1.7	0.922
IST (mm)	10.0 ± 0.8	10.1 ± 0.9	0.680
LVPWT (mm)	9.4 ± 1.3	9.7 ± 1.0	0.365
LVEF, Simpson (%)	64.0 ± 8.0	67.0 ± 13.5	0.344
LVEDD (mm)	43.0 ± 2.5	44.1 ± 3.9	0.241
LVESD (mm)	31.9 ± 4.0	33.0 ± 5.5	0.423
LV mass index (g/m^2)	95.9 ± 14.6	100.2 ± 18.3	0.915

Data are expressed as number only, mean ± standard deviation, or n (%).
ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; DHP, dihydropyridine; HIIT, high-intensity interval training; IST, interventricular septum tickness; LV, left ventricular; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic diameter; LVPWT, left ventricular posterior wall thickness; ModEx, moderate exercise.

Table 2. Mean 24-hour ambulatory blood pressure measurements (ABPM) and renal function at baseline and during follow-up

Parameter	Follw-up (mo)						
	Baseline	6	12	18	24	30	36
	High-intensity interval training group (n = 25)						
Mean 24-hour ABPM (mmHg)							
Systolic	125.8 ± 2.7	–	123.5 ± 2.1*,††	–	121.6 ± 2.2**,††	–	119.7 ± 1.8**,††
Diastolic	75.8 ± 3.0	–	75.1 ± 2.0	–	74.7 ± 2.3	–	74.3 ± 1.8
Creatinine (mg/dL)	1.71 ± 0.10	1.71 ± 0.09	1.70 ± 0.11	1.70 ± 0.11	1.69 ± 0.10††	1.69 ± 0.10††	1.70 ± 0.08††
eGFR (mL/min/1.73 m^2)	45.0 ± 5.0	45.3 ± 5.0	44.9 ± 5.8	45.2 ± 6.0	46.0 ± 6.0†	46.2 ± 6.8†	46.4 ± 8.0†
ACR (mg/g)	67.0 ± 23.2	69.3 ± 1.0	67.0 ± 24.5	65.1 ± 22.0	62.8 ± 12.8†	60.0 ± 25.1†	52.5 ± 19.8†
	Moderate exercise group (n = 25)						
Mean 24-hour ABPM (mmHg)							
Systolic	124.4 ± 4.7	–	120.0 ± 2.1**	–	118.1 ± 2.0**	–	115.5 ± 1.8**
Diastolic	75.0 ± 2.7	–	74.2 ± 1.5	–	73.8 ± 1.3	–	73.0 ± 1.1*
Creatinine (mg/dL)	1.74 ± 0.09	1.68 ± 0.08	1.65 ± 0.13	1.61 ± 0.09**	1.42 ± 0.08**	1.41 ± 0.08**	1.40 ± 0.09**
eGFR (mL/min/1.73 m^2)	41.2 ± 5.5	45.0 ± 5.6	46.5 ± 5.5	48.8 ± 5.0**	52.0 ± 4.1**	52.7 ± 4.2**	53.3 ± 4.0**
ACR (mg/g)	70.5 ± 27.6	65.4 ± 22.8	62.1 ± 20.0	48.0 ± 12.5*	39.3 ± 13.0**	35.1 ± 15.0**	27.3 ± 14.4**

Data presented as mean ± standard deviation.

ACR, albumin:creatinine ratio; eGFR, estimated glomerular filtration rate.

**P* < 0.05 and ***P* < 0.001 vs. baseline values; †*P* < 0.05 and ††*P* < 0.001 to the comparison of the means between groups in the same time point.

Effects of exercise on blood pressure and renal function

Both groups exhibited significant intragroup changes in mean systolic 24-hour ABPM from baseline to 12, 24 and 36 months. There were also significant differences in the mean systolic 24-hour ABPM between the groups at the same time points, as shown in Table 2. However, regarding the mean diastolic 24-hour ABPM, no intragroup changes from baseline to 12, 24 and 36 months were observed in either group, except for the value at 36 months vs. baseline in the ModEx group. There were no significant differences in the mean diastolic 24-hour ABPM between the groups at the same time points, as shown in Table 2. The effects of HIIT and ModEx on creatinine concentration, eGFR and ACR during the follow-up period are also detailed in Table 2.

AF monitoring

During the 3-year follow-up, AF onset was higher in CKD patients who engaged in HIIT (72%) than in those who engaged in ModEx (24%) (hazard ratio [HR], 3.847; 95% confidence interval [CI], 1.694–8.740; $P = 0.0013$ by log-rank test) as shown in Fig. 1. There was no difference in PAF and PersAF between the groups ($P = 0.5323$): 16 subjects in the HIIT group (84%) and all 8 patients in the ModEx group (100%) presented with PAF.

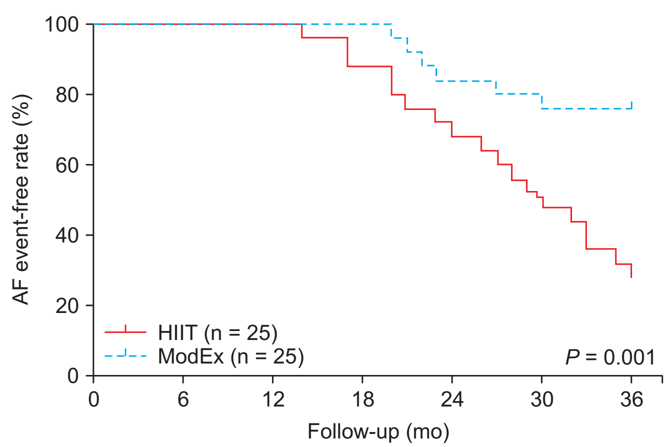

Figure 1. Atrial fibrillation (AF) event-free rate during the follow-up. AF onset was higher in subjects with chronic kidney disease who engaged in high-intensity interval training (HIIT, 72%) compared to those who engaged in moderate exercise (ModEx, 24%) during the 3-year follow-up (hazard ratio, 3.847; 95% confidence interval, 1.694–8.740; $P = 0.001$ by log-rank test).

Effects on echocardiographic parameters

In the HIIT group, the indexed left atrium (LA) volume increased from 30.5 ± 2.1 mL/m^2 at baseline to 31.9 ± 1.1, 33.5 ± 1.5, and 34.2 ± 1.3 mL/m^2 at 12 ($P = 0.0157$), 24 ($P <$

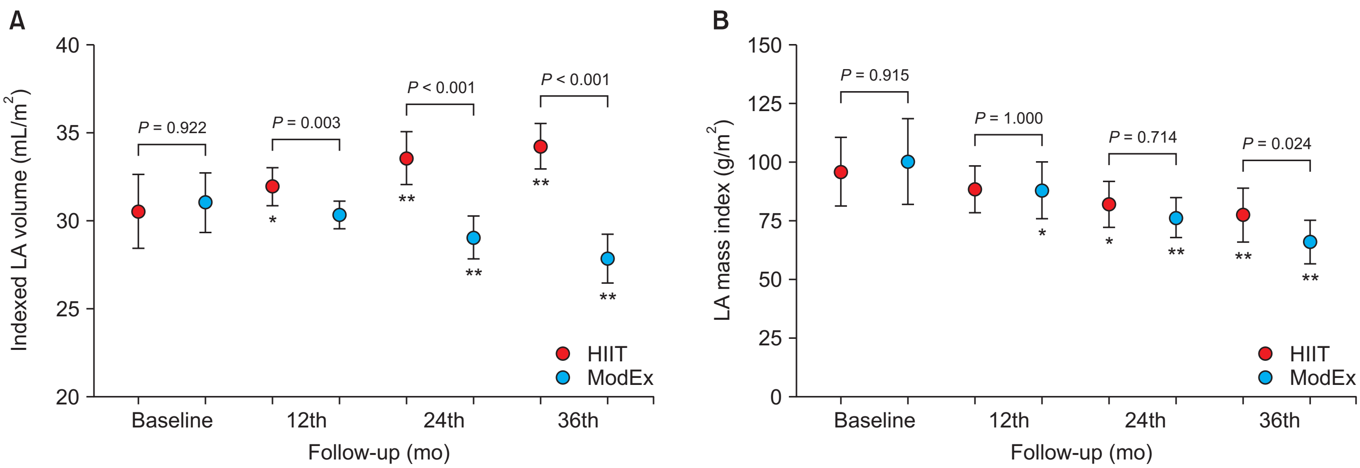

Figure 2. Indexed left atrium (LA) volume and LA mass index during the follow-up. (A) In the high-intensity interval training (HIIT) group, the baseline value of the indexed LA volume (30.5 ± 2.1 mL/m^2) increased to 31.9 ± 1.1, 33.5 ± 1.5, and 34.2 ± 1.3 mL/m^2 at the 12th, 24th, and 36th months, respectively. For the subjects who engaged in moderate exercise (ModEx), the baseline value of the indexed (LA volume 31.0 ± 1.7 mL/m^2) decreased to 30.3 ± 0.8, 29.0 ± 1.2, and 27.8 ± 1.4 mL/m^2 at the 12th, 24th, and 36th months, respectively. (B) Regarding the left ventricular (LV) mass index for the HIIT group, the baseline value (95.9 ± 14.6 g/m^2) decreased to 88.4 ± 10.0, 82.1 ± 9.7, and 77.4 ± 11.5 g/m^2 at the 12th, 24th, and 36th months, respectively. For the subjects that engaged in ModEx, the baseline value of the LV mass index (100.2 ± 18.3 g/m^2) decreased to 88.1 ± 12.2, 76.4 ± 8.5, and 66.0 ± 9.3 g/m^2 at the 12th, 24th, and 36th months, respectively.
*P < 0.05 and **P < 0.001 for values at baseline vs. the values at months 12, 24, and 36.

0.0001), and 36 months (P < 0.0001), respectively. For the subjects who engaged in ModEx, the indexed LA volume decreased from 31.0 ± 1.7 mL/m^2 at baseline to 30.3 ± 0.8, 29.0 ± 1.2, and 27.8 ± 1.4 mL/m^2 at 12 (P = 0.6717), 24 (P < 0.0001), and 36 months (P < 0.0001), respectively. The comparisons between the groups at the same time points are illustrated in Fig. 2A.

Regarding the LV mass index in the HIIT group, the value decreased from 95.9 ± 14.6 g/m^2 at baseline to 88.4 ± 10.0, 82.1 ± 9.7, and 77.4 ± 11.5 g/m^2 at 12 (P = 0.3676), 24 (P = 0.0021), and 36 months (P < 0.0001), respectively. For the subjects who engaged in ModEx, the LV mass index decreased from 100.2 ± 18.3 g/m^2 at baseline to 88.1 ± 12.2, 76.4 ± 8.5, and 66.0 ± 9.3 g/m^2 at 12 (P = 0.0124), 24 (P < 0.0001), and 36 months (P < 0.0001), respectively. The comparisons between the groups at the same time points are presented in Fig. 2B.

Discussion

Our findings demonstrated that in CKD patients with hypertension, improvements in AF onset, renal function, and some echocardiographic parameters were more evident in subjects who engaged in ModEx than in those who engaged in HIIT during a 3-year follow-up period.

Sympathetic super activity plays a key role in the development, maintenance and aggravation of arrhythmias [1]. Undoubtedly, there is an increasing appreciation for the role of the sympathetic system in this setting. The effect of endurance training on renal sympathetic nerve activity has been measured in healthy adults [7], but not in individuals with CKD. The ideal subject population should be considered, as exercise training studies involving patients with CKD often include only the healthiest individuals, which may limit the scope of the findings [34]. Optimizing typical training philosophies and the frequency, intensity, duration and type of exercise may facilitate physiological changes, and thus should be studied.

The average length of previous studies in clinical populations has been approximately 4 months of physical activity at a moderate strength 3 days per week, while training in healthy populations has been considerably shorter in duration [3]. Extended interventions (≥ 4 months) have been more effective in reducing sympathetic activity in other populations; therefore, Howden et al [2] suggested embracing a similar approach in patients with CKD, because intense endurance training in healthy individuals has been verified to have a more pronounced effect on autonomic balance [3], and thus can benefit individuals with high sympathetic tone.

The risk of AF depends on the interplay among individual susceptibility, the environment and the degree of physical activity [35]. Forceful exercise may increase the risk of sudden cardiac death and even AF in some instances; however, habitual moderate physical activity may have several benefits that ultimately reduce the incidence of AF. Lowering heart rate and blood pressure, improving glucose and lipid control, mitigating weight loss, improving endothelial function and lowering systemic inflammation are some of the benefits of exercise that may impede the development of AF [36]. On the other hand, vigorous activity can cause acute catecholamine fluxes, changes in autonomic tone, and atrial stretching, all of which contribute to AF risk [37–40]. Autonomic influences should also be considered to reduce the aggravation of AF [37].

Most studies have investigated the effects of endurance training and vigorous exertion in young and middle-aged adults. In a study of 44,410 men, intense endurance training at age 30 increased the risk of AF later in life, whereas moderate-intensity training reduced this risk [41]. Similar findings were reported for older athletes [10]. A meta-analysis of several small studies demonstrated that the risk of AF development was greater in athletes than in non-athletes, but the subjects were not age-matched, and there was high variability in the level of endurance across the studies [42]. Age, years of training and type of sport all affect the outcomes of such studies, so it is not possible to deduce a net conclusion from them, except that vigorous endurance exercise may have a small role in facilitating AF.

Endurance exercise training clearly lowers sympathetic activity in sympathoexcitatory disease states [3], and is well-tolerated by patients with CKD [5,6]. Blood pressure control is a fundamental component of the management of patients with renal impairment, and altering sympathetic activity is one strategy to reduce blood pressure. Indeed, there is growing appreciation for the role of the sympathetic system in this setting, with recent studies demonstrating that reducing sympathetic activity has favorable effects on blood pressure [43,44]. Such changes consequently improve renal function.

The Cardiovascular Health Study demonstrated that leisure-time activity was associated with a lower AF incidence in a graded manner, with decreasing risk as the intensity increased [10]. The AF incidence was also lower in individuals who engaged in ModEx than in those who did not exercise (HR, 0.72; 95% CI, 0.58–0.89). However, high-intensity exercise was not associated with a significantly reduced risk of AF (HR, 0.87; 95% CI, 0.64–1.19). There is also an inverse relationship between cardiorespiratory fitness and the incidence of AF, especially among obese patients [8]. In a large population-based Swedish cohort, the risk of AF decreased with increasing leisure-time exercise in middle-aged and elderly women [9]. Inactivity and obesity may lead to diastolic dysfunction and left atrial enlargement, thus increasing AF risk, whereas exercise training can improve diastolic function and reduce the left atrial volume. The current evidence suggests that moderate physical activity is associated with improved cardiovascular health, reduced mortality and a reduced risk of AF.

Cardiac magnetic resonance imaging was not used in this study because gadolinium was used, which can lead to nephrogenic systemic fibrosis in individuals with CKD. We chose patients with structurally normal hearts to ensure that there were no other mechanisms involved in the genesis and maintenance of AF. However, our data should be interpreted carefully, given the unblinded non-randomized nature of the study. A large-scale randomized trial with appropriate concealment of treatment and an extended follow-up period will be required to address the potential benefits of the different types of physical activity in CKD patients with hypertension.

In CKD patients with hypertension, improvements in AF onset, renal function, and some echocardiographic parameters were more evident in subjects who engaged in ModEx than in subjects who engaged in HIIT during a 3-year follow-up period. Although encouraging, our data should be considered preliminary, and requires validation in a large population over a longer period.

Conflicts of interest

All authors have no conflicts of interest to declare.

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