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CASE SERIES
Arrhythmias/electrophysiology

A case series of acute responses to high-intensity interval training in four males with permanent atrial fibrillation

Sol Vidal-Almela [1,2], Tasuku Terada [1], Christie A. Cole[1], Carley D. O'Neill[1], Katelyn Comeau[1,2], Isabela R. Marçal[1,2], Andrew L. Pipe [1,3], and Jennifer L. Reed [1,2,4]*

[1]Exercise Physiology and Cardiovascular Health Lab, Division of Cardiac Prevention and Rehabilitation, University of Ottawa Heart Institute, Ottawa, 40 Ruskin Street, Ontario, Canada K1Y 4W7; [2]School of Human Kinetics, Faculty of Health Sciences, University of Ottawa, Ottawa, Canada K1N 1A2; [3]School of Medicine, Faculty of Medicine, University of Ottawa, Ottawa, Canada K1H 8M5; and [4]School of Epidemiology and Public Health, Faculty of Medicine, University of Ottawa, Ottawa, Canada K1H 8M5

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Background Atrial fibrillation (AF) is a serious medical condition and a burgeoning patient population. Chronic exercise training, including high-intensity interval training (HIIT), has been shown to improve symptoms and quality of life in patients with AF. Yet, the acute responses to HIIT in this population remain understudied, leaving clinicians and patients hesitant about prescribing and engaging in high-intensity exercise, respectively.

Case summary This case series describes acute exercise responses [i.e. power output, heart rate (HR), blood pressure (BP), ratings of perceived exertion (RPE), symptoms] to 10 weeks (3 days/week) of HIIT. Participants were four white males (58–80 years old) with permanent AF, co-morbidities (diabetes, coronary artery disease, Parkinson's disease), and physical limitations. The increases in HR and BP during HIIT were modest across all participants, regardless of age and medication use. Differences in RPE were observed; the oldest participant perceived the sessions as more challenging despite a lower HR response. All patients complied with the HIIT prescription of 80–100% of peak power output by week 4. No adverse events were reported.

Discussion Patients' concerns regarding high-intensity exercise may discourage them from participating in HIIT, our results demonstrated no abnormal HR or BP (e.g. hypotension) responses during HIIT or cool-down. These findings align with the typical exercise responses noted in other cardiovascular populations. Notwithstanding the high metabolic demands of HIIT, male patients with permanent AF tolerated HIIT without problem. Further investigation of HIIT as an approach to enable those with AF to recover physical capacity and minimize symptomatology is warranted.

Keywords Acute exercise • Atrial fibrillation • Case report • Exercise training • HIIT • Physical activity • High-intensity interval training

ESC Curriculum 5.3 Atrial fibrillation • 8.7 Prevention and rehabilitation programmes • 8.6 Secondary prevention • 8.1 Sports cardiology

* Corresponding author. Tel: +1 613-696-7392, Fax: +1 613 696 7195, Email: jreed@ottawaheart.ca
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Learning points

- Patients with permanent atrial fibrillation experienced increased heart rate (average +31 to +60 b.p.m.) during high-intensity interval training, which decreased following cool-down (–22 to –67 b.p.m.) without adverse events.
- They were exercising at 80–100% of peak power output by week 4, with an average perceived exertion mostly in the moderate- ($n = 3$) and vigorous- ($n = 1$) intensity range.
- Older patients may experience a greater perceived exertion despite a lower heart rate response. This should be considered when monitoring exercise.

Introduction

Patients with atrial fibrillation (AF) experience a rapid and irregular heart rate (HR), resulting in low exercise tolerance, dyspnoea, fatigue, palpitations, dizziness, and diminished quality of life.[1] Regular exercise training has been shown to increase peak aerobic power ($\dot{V}O_{2peak}$) and quality of life, and reduces AF symptoms, resting HR and blood pressure (BP).[2,3] Such improvements have been reported following 10–12 weeks of high-intensity interval training (HIIT).[2,4] Yet, the acute responses to HIIT in patients with AF remain understudied, leaving clinicians and patients uninformed and hesitant about prescribing and engaging in this form of exercise, respectively.[5,6]

Patients with stable cardiovascular disease tolerate HIIT without an increase in acute adverse exercise responses such as arrhythmias or abnormal HR and BP (e.g. hypotension).[7,8] The acute physiological response [e.g. HR, BP, ratings of perceived exertion (RPE)] to HIIT may differ in patients with AF given their unique HR issues. The asynchronous contractions typical of AF result in a rapid and irregular HR, reduced stroke volume,[9] and diminished cardiac output. Autonomic dysfunction often co-exists with AF; most patients with AF demonstrate hypertension.[10] Further, AF can impair ventilatory efficiency during exercise[11]; thereby increasing the RPE associated with HIIT. The acute responses may become less pronounced as patients participate regularly in HIIT, and may differ by age. Ageing is associated with a diminished increase in HR (older males: +105% vs. younger males: +166%),[12] greater increase in BP (older males: +35% vs. younger males: +22%),[12] and inconsistent reporting of RPE[13] during exercise. We need acute exercise studies to inform patients and clinicians of the typical response to HIIT and demonstrate the applicability of this modality in managing AF.

This case series describes acute HR, BP, and RPE responses to HIIT in four male patients with permanent AF. Secondarily we compare the acute exercise responses between the beginning and end of a 10-week HIIT programme, and describe the adherence to HIIT.

Timeline

Methodology

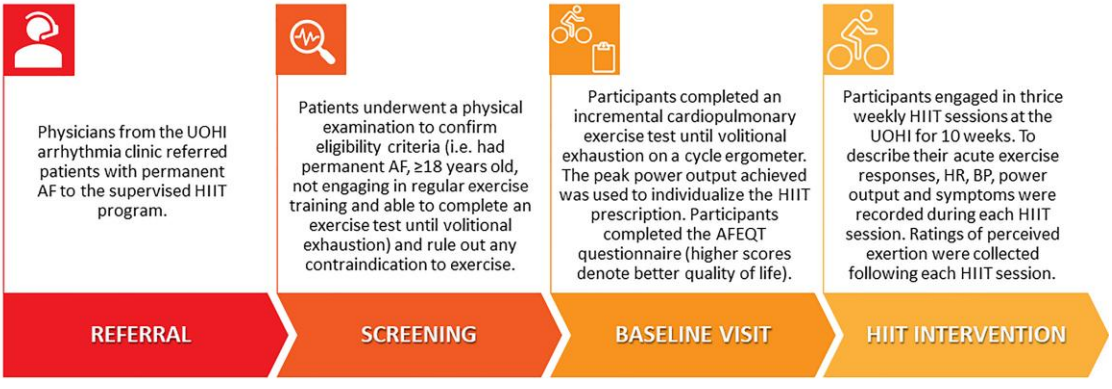
This study was a retrospective case series. Informed consent was obtained from the four participants and approval from the Ottawa Health Science Network Research Ethics Board (#20140379-01H). The study procedures are summarized in the *Timeline*. Physicians from the University of Ottawa Heart Institute (UOHI) arrhythmia clinic referred patients who met the eligibility criteria: (i) permanent AF, (ii) ≥18 years old, (iii) not engaging in regular exercise training and, (iv) able to perform an exercise test on a cycle ergometer. During the exercise test, the power output was increased every minute until volitional exhaustion. The peak power output (PPO) achieved was used to individualize the HIIT prescription by calculating 80–100% of PPO for the 30 s high-intensity bouts and 25% of PPO for the 30 s low-intensity bouts (see *Figure 1*).

HIIT intervention

Participants engaged in thrice weekly HIIT sessions at the UOHI for 10 weeks. The exercise mode was cycling on a stationary cycle ergometer. Research staff supervised each 23 min HIIT session one-on-one. The HIIT prescription (see *Figure 1*) remained unchanged throughout the 10-week programme. The main conditioning session involved 16 min of HIIT consisting of 2 × 8 min blocks separated by 4 min of active or passive recovery, according to the patient's choice.

Acute measures during each HIIT session throughout 10 weeks

Power output (in watts), HR, BP, and any symptoms were recorded during each HIIT session. Chest-worn Polar HR monitors (Polar RS800CX, Polar Electro Oy, Finland) were used to measure HR. Limited research has shown that AF does not reduce HR monitor accuracy.[14] Research staff recorded the power output and HR towards



Timeline of the case series. AF, atrial fibrillation; AFEQT, Atrial Fibrillation Effect on QualiTy of life questionnaire; BP, blood pressure; HIIT, high-intensity interval training; HR, heart rate; UOHI, University of Ottawa Heart Institute.

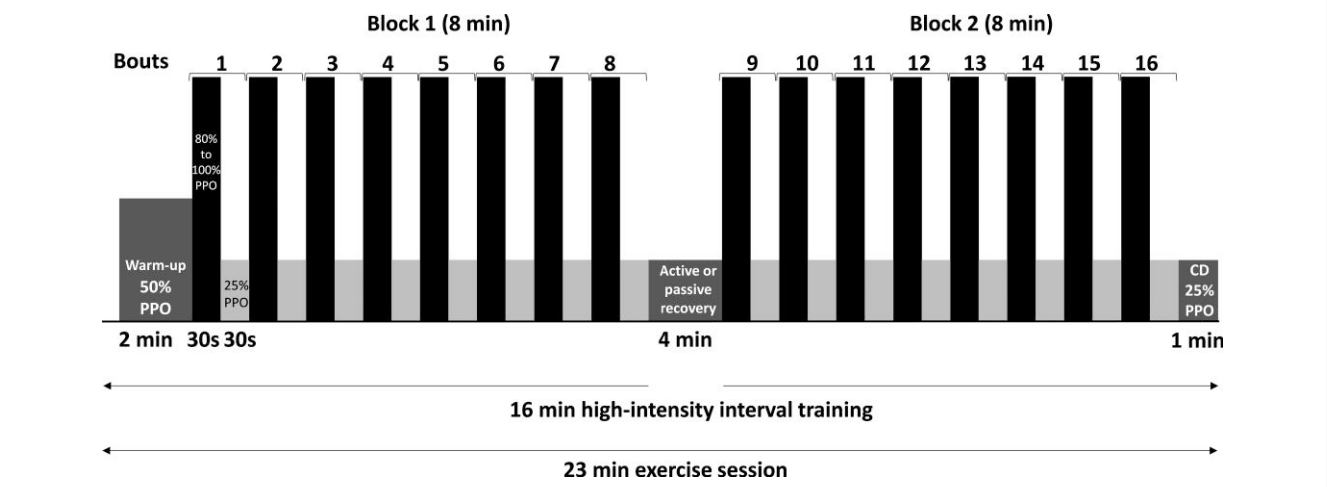


Figure 1 High-intensity interval training protocol consisting of 2 × 8 min blocks separated by 4 min of active or passive recovery, according to the patient's choice. CD, cool-down.

the end of each interval. Blood pressure was measured using an automated BP monitor (Bp-TRU, Canada) while the patient was sitting on the cycle ergometer immediately following the warm-up and cool-down, and during the last minute of the recovery between blocks. Particpants' RPE were recorded at the end of each session using the 6–20 Borg scale. Any symptoms/comments (e.g. dizziness, musculoskeletal limitations) reported by patients were noted.

Cases presentation

The patient characteristics, medications, and exercise prescription are presented in *Table 1*. Acute responses to HIIT are shown in *Figures 2–5*. Unless otherwise noted, data for each participant are presented as means ± standard deviations, as the acute responses (e.g. HR during each high-intensity bout) were averaged using data from all exercise sessions.

Case 1

A 58-year-old male with asthma and obesity [body mass index (BMI): 33.4 kg/m^2], a $\dot{V}O_{2peak}$ of 22.5 mL/kg/min and an overall AF Effect on QualiTy of life (AFEQT) score of 98/100 points (higher scores denote better quality of life). The highest PPO achieved during the exercise test was 193 W, with a peak HR of 173 b.p.m. and BP of 170/80 mmHg. Mean HR increased during HIIT (warm-up: 105 ± 10 b.p.m.; bout 1 to bout 8: 121 ± 15 to 130 ± 16 b.p.m.; bout 9 to bout 16: 123 ± 14 to 148 ± 20 b.p.m.) and decreased following cool-down (114 ± 8 b.p.m.). Mean BP was as follows (systolic/diastolic BP): warm-up: 111 ± 8/82 ± 6 mmHg; break following bout 8: 116 ± 11/85 ± 8 mmHg; cool-down: 114 ± 9/83 ± 7 mmHg. The patient felt 'very fatigued' during some sessions and 'strong' in others. RPE ranged between 12 (light) and 15 (hard). The patient reported knee stiffness during/following several HIIT sessions, yet attended 30 exercise sessions (100% adherence).

Case 2

A 67-year-old male with low back pain and an AFEQT score of 73/100 points. The patient had previously undergone four ablations, had a healthy BMI of 23.2 kg/m^2 and a $\dot{V}O_{2peak}$ of 25.7 mL/kg/min. The PPO reached during the exercise test was 180 W, with a peak HR of 155 b.p.m. and BP of 142/70 mmHg. Mean HR increased during HIIT (warm-up: 93 ± 18 b.p.m.; bout 1 to bout 8: 140 ± 18 to 153 ± 9 b.p.m.; bout 9 to bout 16: 151 ± 16 to 164 ± 10 b.p.m.), while BP remained constant (warm-up: 111 ± 8/77 ± 3 mmHg; break following bout 8: 112 ± 9/81 ± 9 mmHg; cool-down: 114 ± 9/79 ± 9 mmHg). Following cool-down, HR decreased to 86 ± 24 b.p.m. RPE ranged between 11 (very light) and 16 (hard). Frequently reported notes from the HIIT sessions included lack of motivation/low energy and knee stiffness. The patient completed 22/30 sessions (73% adherence).

Case 3

A 74-year-old male with multiple co-morbidities including obesity (BMI: 33.9 kg/m^2) and diabetes, a $\dot{V}O_{2peak}$ of 14.5 mL/kg/min and an AFEQT score of 73/100 points. The PPO reached during the exercise test was 156 W, with a peak HR of 174 b.p.m. and BP of 180/90 mmHg. Abnormal ST depression was noted during the exercise test, beginning at 153 b.p.m. As per protocol within our cardiac rehabilitation programme and exercise training guidelines,[15] the study staff were advised to keep the patient's HR 10 b.p.m. under this ischaemic threshold. To keep the HR below 143 b.p.m., a few low-intensity bouts were extended by 10–30 s during 14 HIIT sessions. Mean HR increased during HIIT (warm-up: 75 ± 8 b.p.m.; bout 1 to bout 8: 108 ± 9 to 137 ± 22 b.p.m.; bout 9 to bout 16: 121 ± 14 to 132 ± 20 b.p.m.) and decreased following cool-down (92 ± 6 b.p.m.). Mean BP was as follows: warm-up: 130 ± 9/79 ± 8 mmHg; break following bout 8: 144 ± 12/79 ± 9 mmHg; cool-down: 141 ± 9/84 ± 9 mmHg. RPE ranged between 11 (light) and 13 (somewhat hard). Frequent symptoms reported during HIIT included leg fatigue and dyspnoea. The patient attended 29/30 sessions (97% adherence).

Case 4

An 80-year-old male with Parkinson's disease and stable coronary artery disease following a percutaneous coronary intervention. The patient was overweight (BMI: 29.2 kg/m^2), experienced low back pain, had a $\dot{V}O_{2peak}$ of 15.7 mL/kg/min and an AFEQT score of 88/100 points. The exercise test was terminated at a PPO of 140 W, with a peak HR of 120 b.p.m. and BP of 170/68 mmHg. HR increased during the first portion of HIIT (warm-up: 82 ± 12 b.p.m.; bout 1 to bout 8: 107 ± 15 to 121 ± 17 b.p.m.; bout 9 to bout 16: 116 ± 16 to 115 ± 12 b.p.m.) and decreased following cool-down (88 ± 12 b.p.m.). Mean BP was as follows: warm-up: 139 ± 14/78 ± 8 mmHg; break following bout 8: 137 ± 21/78 ± 7 mmHg; cool-down: 136 ± 12/74 ± 7 mmHg. Most RPE ranged from 14 (somewhat hard) to 17 (hard). Muscle soreness and fatigue were

Table 1 Characteristics of four white male patients with permanent atrial fibrillation

	Case 1	Case 2	Case 3	Case 4
Age (years)	58	67	74	80
Height (cm)	168.9	176.1	180.2	172.5
Body mass (kg)	95.4	71.9	110.0	86.9
BMI (kg/m^2)	33.4	23.2	33.9	29.2
Waist circumference (cm)	112.0	86.5	119.5	102.5
Resting systolic BP (mmHg)	98	120	142	126
Resting diastolic BP (mmHg)	70	70	80	70
Resting heart rate (b.p.m.)	109	91	81	73
$\dot{V}O_{2peak}$ (mL/kg/min)	22.5	25.7	14.5	15.7
Peak power output (W)	193	180	156	140
Prescription for high-intensity bouts (W)	154–193	144–180	123–156	112–140
AFEQT (points)				
Overall	98	73	73	88
Symptoms	100	88	75	92
Daily activities	96	83	67	83
Treatment concern	100	72	83	97
Treatment satisfaction	100	0	58	67
Co-morbidities				
	Dyslipidaemia Obesity Asthma	Low back pain	Dyslipidaemia Hypertension Obesity Stable CAD Type 2 diabetes	Low back pain Parkinson's disease Stable CAD
Procedures				
	—	Four ablations	—	PCI
Medications				
Anti-coagulant	—	Rivaroxaban	Rivaroxaban	Warfarin
Anti-platelet	Aspirin	—	—	—
Anti-hypertensive	—	—	Ramipril	—
Anti-dyslipidaemic	Atorvastatin	—	Rosuvastatin	—
β-Blocker	—	—	Bisoprolol	—
Other	Tiotropium bromide and zenhale (asthma)	Alendronic acid	Metformin and glicazide (diabetes) Dutasteride (prostate hyperplasia)	Levocarb (Parkinson) Alfuzosin (prostate hyperplasia)

AFEQT, Atrial Fibrillation Effect on QualiTy of life—lower scores denote more disability; BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; PCI, percutaneous coronary intervention; $\dot{V}O_{2peak}$, peak aerobic power.

frequently reported during the programme. The patient missed several consecutive HIIT sessions due to worsening back pain, attending 23/30 sessions (77% adherence).

Acute responses at the beginning and end of the 10-week HIIT programme

Figure 6 shows a comparison of the acute exercise responses between the last and first session. In the last session, all participants complied with the HIIT prescription; in the first session, two participants only completed 8 and 12 of the 16 high-intensity bouts. All patients sustained a greater average power output during the last vs. first HIIT session (Case 1: +31 W, Case 2: +35 W, Case 3: +33 W, Case 4: +11 W). The mean HR response was heightened in Cases 2 (+26 b.p.m.) and 3 (+32 b.p.m.) and declined in Cases 1 (−16 b.p.m.) and 4 (−24 b.p.m.) during the last vs. first session. We observed differences over time in the patient relationship with RPE. Case 1 reported a greater exertion (last: 15, first: 11 points), Case 2 reported similar RPE (12 points), and Case 4 reported a three-point lower RPE (last: 14, first: 17 points) following the last vs. first HIIT session.

Discussion

Patients with AF living with several co-morbidities (e.g. diabetes, coronary artery disease, Parkinson's disease) and physical limitations, and on different medications were able to engage in HIIT without adverse events or worsening symptoms such as chest pain or unusual shortness of breath. The underlying cause of increasing back pain in Case 4 was unclear. Modest increases in HR and BP were experienced by all patients. The average increase in HR from the warm-up to the HIIT portion ranged from +31 to +60 b.p.m., and the average reduction

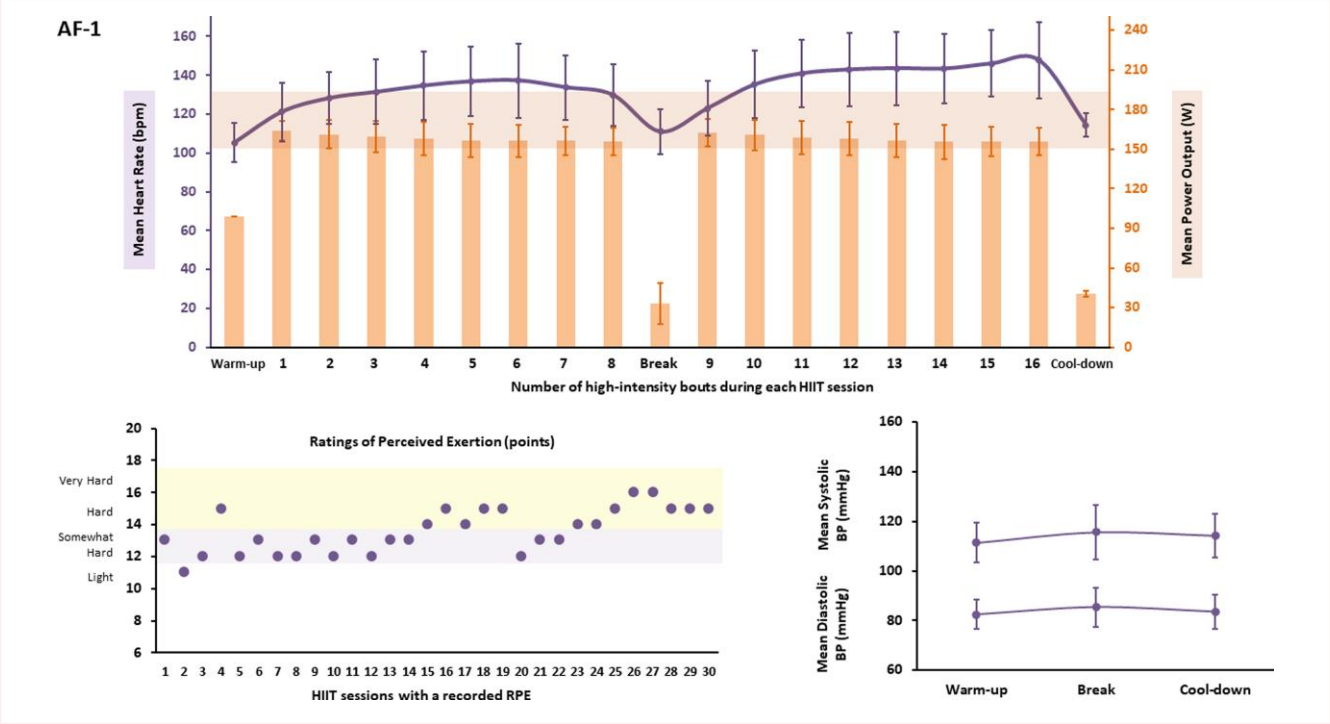


Figure 2 Power output, blood pressure, heart rate, and ratings of perceived exertion during HIIT in Case 1. The highlighted range in the top figure represents 80–100% of the peak power output. The highlighted areas in the ratings of perceived exertion section represent moderate-intensity exercise (12–13 points) and vigorous-intensity exercise (14–17 points). BP, blood pressure; HIIT, high-intensity interval training; RPE, ratings of perceived exertion.

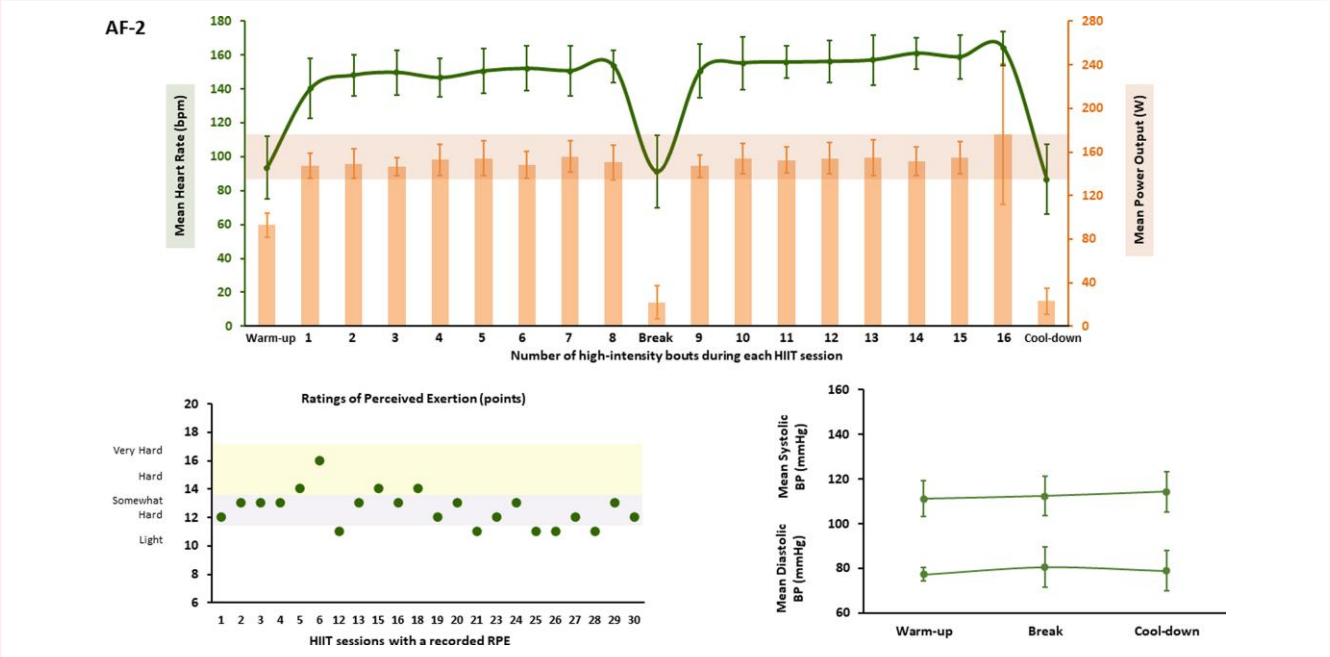


Figure 3 Power output, blood pressure, heart rate, and ratings of perceived exertion during HIIT in Case 2. The highlighted range in the top figure represents 80–100% of the peak power output. The highlighted areas in the ratings of perceived exertion section represent moderate-intensity exercise (12–13 points) and vigorous-intensity exercise (14–17 points). BP, blood pressure; HIIT, high-intensity interval training; RPE, ratings of perceived exertion.

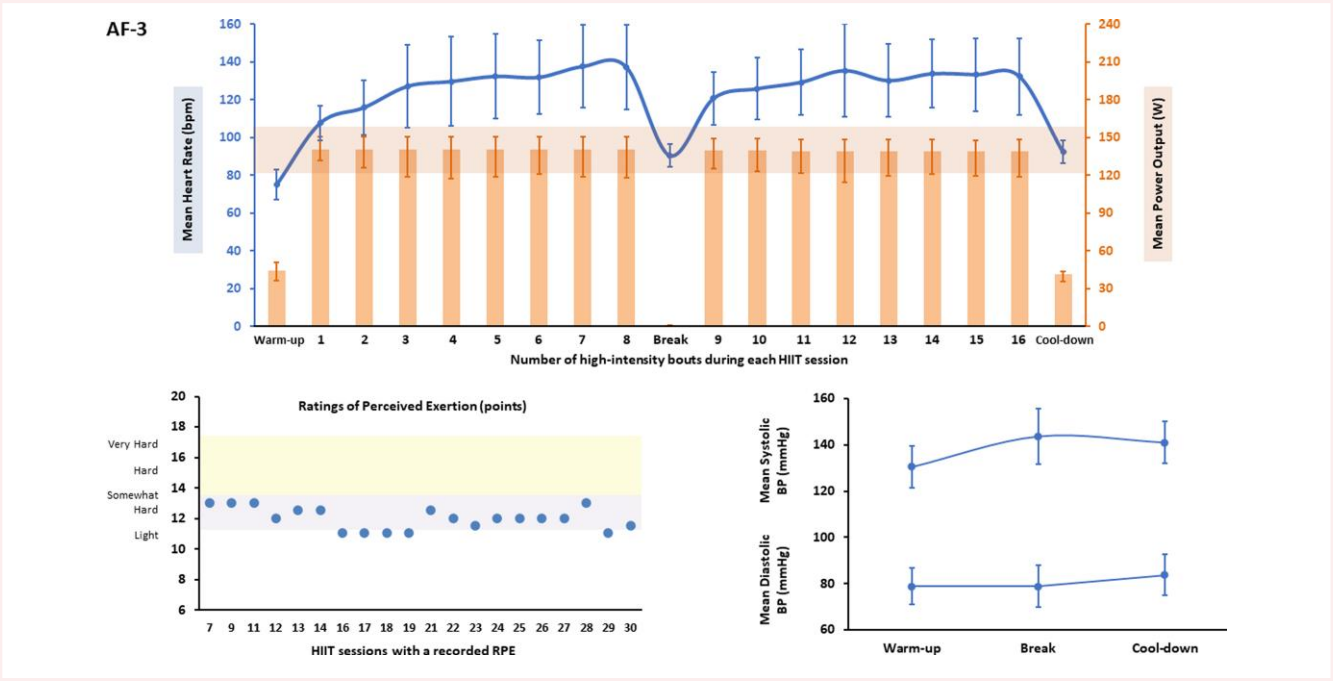


Figure 4 Power output, blood pressure, heart rate, and ratings of perceived exertion during HIIT in Case 3. The highlighted range in the top figure represents 80–100% of the peak power output. The highlighted areas in the ratings of perceived exertion section represent moderate-intensity exercise (12–13 points) and vigorous-intensity exercise (14–17 points). BP, blood pressure; HIIT, high-intensity interval training; RPE, ratings of perceived exertion.

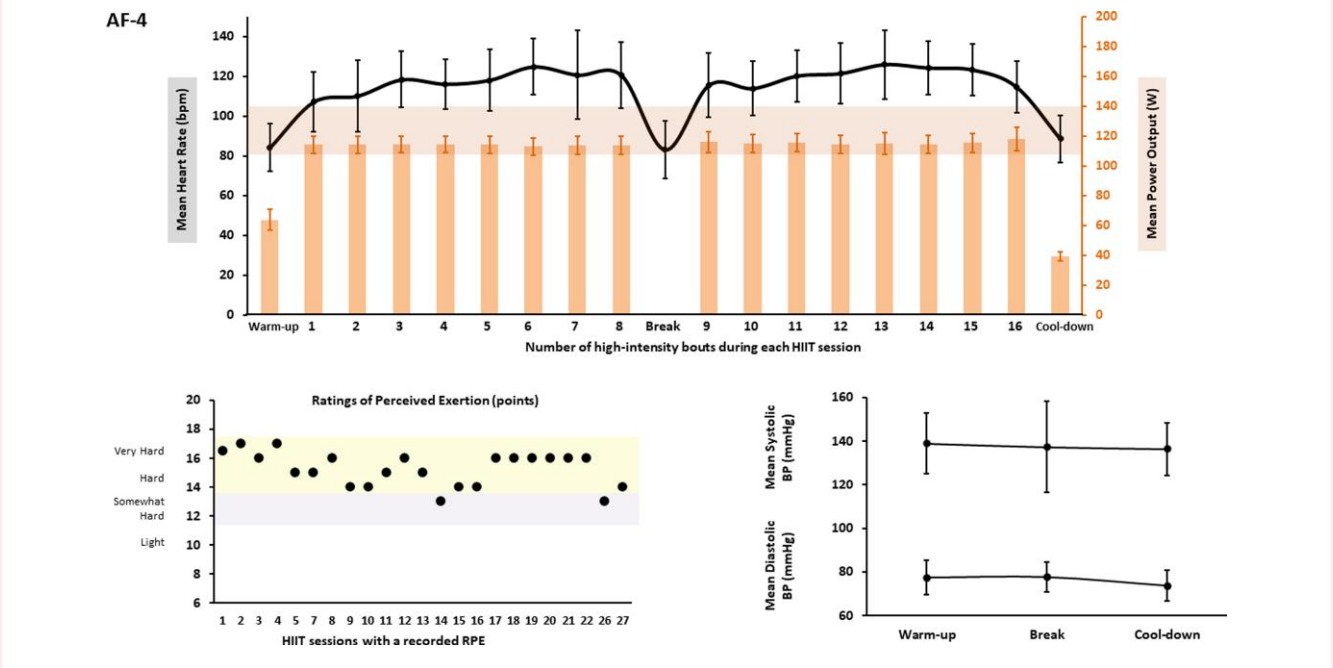


Figure 5 Power output, blood pressure, heart rate, and ratings of perceived exertion during HIIT in Case 4. The highlighted range in the top figure represents 80–100% of the peak power output. The highlighted areas in the ratings of perceived exertion section represent moderate-intensity exercise (12–13 points) and vigorous-intensity exercise (14–17 points). BP, blood pressure; HIIT, high-intensity interval training; RPE, ratings of perceived exertion.

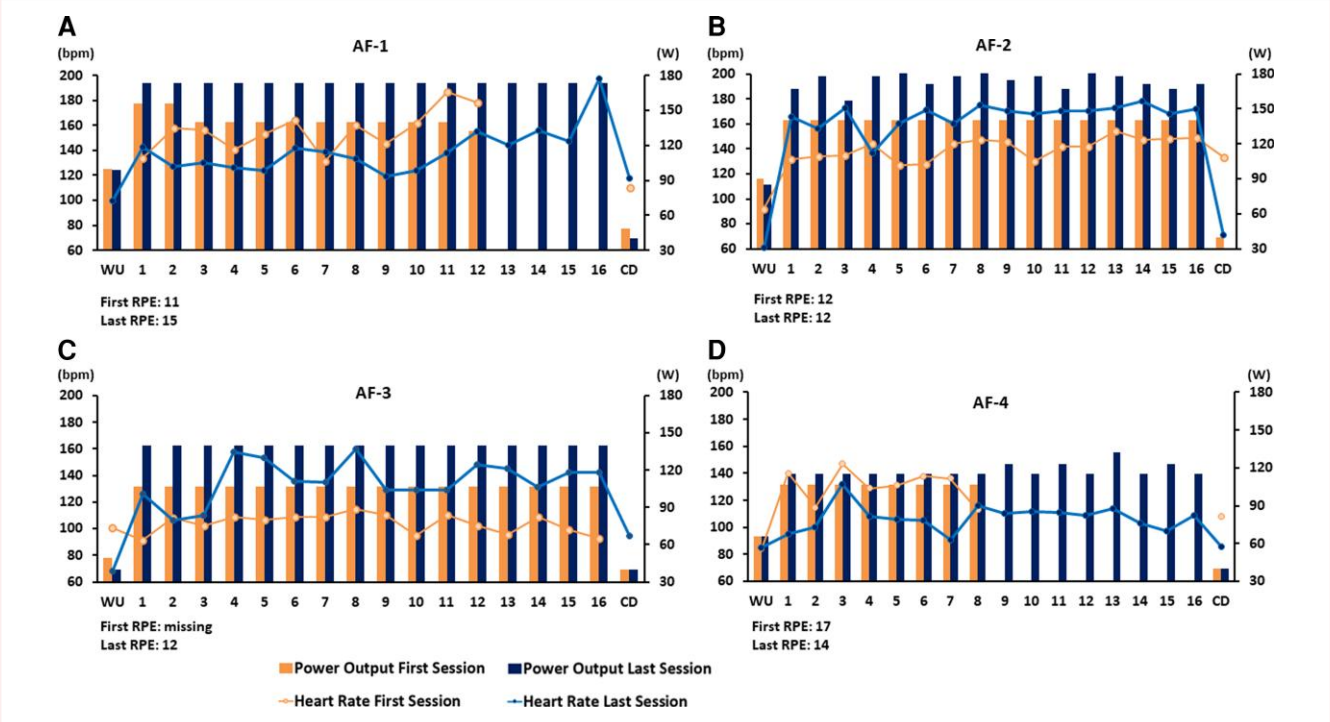


Figure 6 Acute heart rate and power output of the first and last HIIT session. (*A*) Case 1; (*B*) Case 2; (*C*) Case 3; (*D*) Case 4. CD, cool-down; RPE, rating of perceived exertion; WU, warm-up.

following cool-down ranged from –22 to –67 b.p.m. Our results align with findings in other cardiovascular populations,[7,8,16] suggesting that the presence of AF does not compromise the physiological response to high-intensity exercise. Interestingly, Case 2 maintained a high mean HR during HIIT without a marked increase in BP; the peak BP during this patient's exercise test was also modest (142/70 mmHg).

Several reasons may have led to different RPE between participants across the 30-session programme. After participating regularly in HIIT, they may have become more confident in their ability to exercise[17] and substantially increased their exercise intensity, thus reporting higher RPE. In contrast, other participants may have become more conditioned and perceived a lower effort while engaging in similar exercise intensities, leading to lower RPE over time.

The four patients with permanent AF were highly adherent (100, 73, 97, and 77%) to three weekly HIIT sessions over 10 weeks. The repeated high-intensity bouts of HIIT may lead to multiple successful experiences, in turn increasing patient's self-efficacy and enhancing regular exercise participation.[18] Watts are an objective measure of power which may be more appropriate than HR_{peak} for exercise prescription in patients with AF.[19] RPE may also be a simple tool that patients can use to self-monitor exercise intensity during HIIT.[19] All patients exercised within their 80–100% of PPO by week 4. Patients with AF have low exercise tolerance[11] and may need a familiarization period (1–3-week) before adhering completely to a high-intensity protocol. Since all patients were able to sustain a greater power output over time, it seems reasonable that patients with AF should gradually increase the frequency, intensity and/or duration of HIIT as they adapt to a given activity pattern.

No major differences in the HIIT response between patients of several age ranges were observed. The PPO and consequent power output prescription were lowest in the oldest patient and highest in the youngest. The oldest patient (80 years) reported the highest mean RPE (15 points), despite the lower absolute power output prescribed and lower mean HR during the high-intensity bouts (119 b.p.m.) when compared to the other participants (Case 1, 58 years: 14 points and 136 b.p.m.; Case 2, 67 years: 13 points and 153 b.p.m.; Case 3, 74 years: 12 points and 129 b.p.m.). These small differences may be related to declines in absolute $\dot{V}O_{2peak}$, which can impact PPO, and in HR_{peak} associated with age.[20] Clinicians monitoring exercise should consider that older patients with AF may experience a greater perceived exertion despite a lower HR response. Medications may have also impacted the acute responses to HIIT as they can modify the haemodynamic response at rest and during exercise.[15]

Patients need clear advice to overcome fears of exercising following an AF diagnosis.[5,6] Our limited pilot investigation underscores the need for further investigation of the role of HIIT in the management of AF in order that this exercise modality might more confidently be prescribed and provided to those with this condition. Future studies examining acute effects of exercise in AF should include: (i) a larger and more generalizable sample, (ii) several HIIT protocols, and (iii) additional mechanistic and patient-reported measures.

Lead author biography

Originally from Spain, Sol is an ACSM certified Clinical Exercise Physiologist who completed an M.Sc. in Clinical Exercise Physiology at Liverpool John Moores University, England, and is now a Ph.D. candidate in Human Kinetics in the Exercise Physiology and Cardiovascular Health Lab at the University of Ottawa Heart Institute, Canada. She has a strong interest in advancing our understanding of the response to acute and chronic exercise in clinical populations such as patients with atrial fibrillation.

Supplementary material

Supplementary material is available at *European Heart Journal—Case Reports* online.

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Slide sets: A fully edited slide set detailing these cases and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written informed consent for submission and publication of this case report, including the associated text, have been obtained from the four participants in line with COPE guidance.

Conflict of interest: None declared.

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