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Comparative effects of moderate-intensity interval training on sleep quality and functional capacity in atrial fibrillation patients with two types of sleep apnea

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Abstract

Introduction. This study aimed to examine the effects of moderate-intensity interval training (MIIT) on the quality of sleep and functional capacity in atrial fibrillation (AF) patients with different presentations of sleep apnoea after coronary artery bypass graft (CABG) surgery.

Methods. 18 participants with AF and sleep apnoea aged 45–65 years were assigned into two groups: AF with obstructive sleep apnoea group (group A, $n_1 = 9$) and AF with mixed sleep apnoea group (group B, $n_2 = 9$). Both groups received MIIT for ten weeks (3 sessions / week) and medical treatment (i.e., Continuous Positive Airway Pressure and drug therapy). Exclusion criteria were unstable cardiac comorbidities and neurological/musculoskeletal limitations to exercise intervention. Outcome measures included sleep parameters collected from the actigraphy, overall sleep quality rating domain of the Pittsburgh Sleep Quality Index (PSQI), and six-minute walk distance (6-MWD).

Results. Significant changes were present in the means of all outcomes in group A ($p < 0.05$) and two outcomes (i.e., cut points & 6-MWD) in group B compared to baseline ($p < 0.05$). Also, there were significant differences in the absolute mean changes from baseline (Δ) between the two groups, in favour of group A, in sleep latency ($p < 0.001$), total sleep duration ($p = 0.026$), sleep efficiency ($p < 0.001$), overall sleep quality rating item of the PSQI ($p = 0.001$), and 6-MWD ($p = 0.008$).

Conclusions. MIIT can be a supplementary therapeutic intervention that could contribute to greater positive changes in sleep quality and functional capacity in AF patients with obstructive sleep apnoea rather than in AF patients with mixed sleep apnoea post-CABG. MIIT could enhance the functional capacity independent of improving sleep quality in patients with AF and mixed sleep apnoea post-CABG.

Key words: sleep apnoea, atrial fibrillation, moderate-intensity interval training, sleep quality, functional capacity, 6-minute walk distance

Introduction

Atrial fibrillation (AF) is the most common type of cardiac arrhythmia worldwide and is associated with a two to five times increased risk of coronary heart disease, heart failure, and stroke; AF accounts for 14% of all strokes [1, 2]. Sleep-disordered breathing, a major cause of reduced sleep quality, is highly prevalent in patients with AF, varying from 70% to 86%, with moderate-to-severe sleep-disordered breathing affecting more than 40% of AF patients [3]. Sleep-disordered breathing, independent of age, sex, body mass index, and coexisting hypertension or heart failure, is associated with an increased AF burden and increased incidence of major cardiovascular events [3, 4]. Obstructive sleep apnoea (OSA) and central sleep apnoea (CSA) are two different types of sleep-disordered breathing reported in patients with AF and can have unfavourable effects on AF through variable pathophysiological mechanisms [4–6]. Compared to OSA, CSA involves no physical obstruction in the upper airways, but a problem in the brain stem exists preventing the transmission of signals to the working respiratory muscles [6]. Some patients may present with complex or mixed sleep apnoea (mixed SA) exhibiting characteristics of both central and obstructive sleep apnoea [7]. Patients with different presentations of sleep apnoea could have variable responses to exercises [8].

Exercise contributes to improved sleep quality in patients with obstructive sleep apnoea owing to exercise-induced alterations in selected pathophysiologic mechanisms involved in the condition [9]. Moderate-intensity aerobic exercise, but not vigorous exercise, improves the quality of sleep as per a recent meta-analysis [10]. Further, the current international guidelines highlight the importance of physical exercises, particularly the moderate-intensity type, in the management of patients with atrial fibrillation [11]. The potential benefits of aerobic exercises have been investigated previously in heart failure patients [12, 13] and patients with coronary artery disease [14,15] with coexisting OSA and CSA. However, in AF disease, no previous study has compared the responses to moderate-intensity interval training (MIIT) in AF patients with either obstructive or mixed sleep apnoea. Based on the above, this research aimed to assess whether different responses to MIIT exist in AF patients with two presentations of sleep apnoea (i.e., OSA or mixed SA) concerning sleep quality and functional capacity. The results of this study may add a piece of knowledge to the existing literature about the supplemental role of exercise therapy in the management of AF patients with sleep apnoea.

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Subjects and methods

Study design and settings

This was a prospective, two-parallel arm, exercise-based intervention study with an allocation ratio of 1:1 and was conducted during a time frame of 12 months in the Physiotherapy Unit at the National Heart Institute in Egypt.

Subjects

Eighteen patients with AF and sleep apnoea, confirmed by echocardiography and polysomnography, participated in this study and completed the final analysis. They were recruited by referral from a cardiologist from the outpatient clinic at the National Heart Institute in Egypt. First, we recruited 20 patients; one female patient with mixed SA attended only the baseline assessment and did not attend the training or the final assessment, and another female patient with OSA withdrew from the study by the 4th week, resulting in a drop-out rate of 10%. The flow of participants throughout the study is shown in Figure 1. Inclusion criteria were AF, obstructive sleep apnoea, mixed sleep apnoea, ages from 45 to 65 years old, both sexes, previous coronary artery bypass graft (CABG) surgery, medical stability, and complaint of poor sleep quality (i.e., score ≥ 2 of the overall sleep quality rating item of the PSQI). Exclusion criteria were patients with coexisting unstable cardiac morbidities, and neurological or musculoskeletal conditions that preclude exercise intervention. Eligible patients were divided into two groups according to the clinical presentation of sleep apnoea: AF patients with OSA (group A or OSA group) and AF patients with mixed SA (group B or mixed SA group). The two groups received the same medical treatment and exercise intervention for ten weeks.

Evaluations

Actigraphy

There is an evidence-based recommendation for the use of actigraphy in sleep research and the clinical care of patients with sleep abnormalities [16]. A wrist actigraph (Mini Mitter Co. Inc., USA) was used in the present study at baseline and post-intervention to record activities continuously during daytime and sleeping [17, 18]. The data was collected from the Mi Fit application and was then transferred to proprietary software installed on a computer. The software automatically scores sleep/wake cycles and then estimates sleep parameters for each 24-hour period. Finally, the data was imported into a standard Excel spreadsheet for statistical analysis [19].

Sleep parameters collected from the actigraphy

Sleep latency (SL): refers to the period in minutes from the time the subject went to bed to the start of persistent sleep [19].

Total sleep duration (TSD): refers to the total duration actually slept, encompassing the deep sleep duration (DSD) and the light sleep duration (LSD) [20].

Sleep efficiency (SE): defined as the ratio of total sleep duration to the entire time in bed, expressed as a percentage [20].

Sleep fragmentation index (SFI): refers to the ratio of the number of awakenings to the total sleep time in minutes and is an indicator of restlessness or nocturnal movement [19].

Cut points: These are the numbers displayed on the actigraph to give a picture of the activity level affecting sleep fragmentation and quality [21].

Pittsburgh Sleep Quality Index (*PSQI*)

This is a reliable and valid questionnaire used to measure the quality and patterns of sleep in different populations [22]. The Arabic version of the PSQI was used in the present study [23]. The PSQI consists of several sections, of which the overall sleep quality rating domain was selected to rate patients' overall quality of sleep at baseline and after the intervention. The rating of overall sleep quality was done by recording either of four responses as follows: 'very good' → scored as 0, 'Fairly good' → scored as 1, 'Fairly bad' → scored as 2, and 'Very bad' → scored as 3 [22].

Six-minute walking test (*6-MWT*)

The 6-MWT was performed in the present study at the baseline and post-intervention as described by Agarwala et al. [24], as a valid and objective sub-maximal exercise test for functional capacity assessment. The patients were instructed to walk as far as they could at their own pace for a period of 6 minutes. A 30-metre unimpeded track marked by 2 cones at its ends was used in the test. Before the test, specific instructions were given to the patients about the procedure of the test, including information about the permission to slow down or stop as necessary and resume walking again as soon as they were able to. During the test, the patients were monitored via telemetry. Signs and symptoms of physical activity

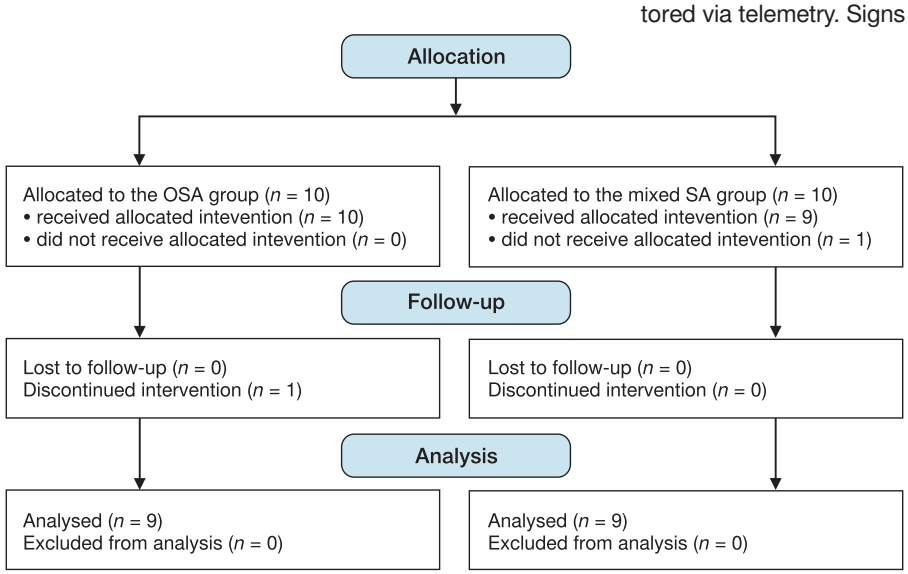

Figure 1. Flowchart of the study

intolerance, such as severe fatigue, chest pain, dyspnoea, or dizziness, were also monitored during the test. After the end of the test, the total distance covered during the 6 minutes was measured [i.e., 6-minute walking distance (6-MWD)] and the maximal heart rate (HRmax) attained during the test was determined.

Electrocardiogram (ECG) telemetry

An ECG telemetry device (ECAT MCT monitor, Mednet, USA) was used during the 6-MWT and exercise training sessions for continuous monitoring of ECG signals of the patients. The ECG telemetry system involves four adhesive electrodes secured around the patient's chest and a wireless connection with a screen displaying the heart rate and rhythm. This system was used to detect any abnormal responses during exercise test/training (e.g. ventricular tachycardia, or depression of the ST-segment ≤ 3 mm), and to produce alarms about the need to terminate the exercise. Also, the ECG telemetry provided information on the need to reduce the exercise intensity if the patient's exercise heart rate exceeded the targeted heart rate (THR).

Interventions

Medical treatment

The patients in the two groups used continuous positive airway pressure (CPAP) at night throughout the study. They also received antihypertensives and antiarrhythmics (beta-blockers and calcium channel blockers). Sedatives were prohibited during the study period as the administration of sedatives in OSA patients worsens the obstruction of the pharynx.

Exercise intervention

The patients in both groups (i.e., OSA and mixed SA groups) received the same exercise intervention (i.e., moderate-intensity interval training: MIIT). Both groups performed 3 exercise sessions per week for 10 weeks. Exercise training was prescribed according to the FITT principle recommended by the American College of Sports Medicine [25] as follows: *Frequency*: 3 sessions/week. *Intensity:* Moderate-intensity exercise was prescribed during 4 work phases of the exercise session at a THR of 55–75% HRmax and low-intensity exercise was implemented during 3 recovery phases of the exercise session at a THR of 45–50% HRmax [26]. *Time*: 43 minutes (i.e., 5 min warm-up, 4 min × 4 work bouts, 4 min × 3 recovery bouts, and 10 min cool-down). *Type*: An interval training consisting of 4 bouts of moderate-intensity exercises interspersed with 3 bouts of low-intensity exercises [26], performed on an electric bicycle ergometer (Biodex LBC, Biodex Inc., New York). Before the beginning of training, the seat height and handlebar were adjusted according to the patient's body height and arm length, and this was recorded to be standardised for the patient during each exercise session. All sessions were held in the morning. Adverse signs and symptoms of exercise intolerance (i.e., severe fatigue, chest pain, dyspnoea, or dizziness) were monitored and recorded during exercise sessions. The exercise was stopped immediately if requested by the patient. All patients were educated on precautions to exercise and guidelines for stopping. The adherence of the participants to the MIIT was good and all of them completed 30 exercise sessions.

Statistical analysis

Statistical analysis was conducted according to Morgan [27]. At first, the normality of the data distribution was assessed by the Kolmogorov-Smirnov test and the assumption of homogeneity of variances of the data across the two groups was tested by Levene's test. Square root data transformation was needed for some data to ensure the normal distribution and/or the homogeneity of variances across groups before using parametric statistics. The absolute mean change from the baseline (Δ) of each variable was calculated and considered an independent outcome. The paired *t*-test was used to compare the mean values of the variables within each group before and after the interventions. The unpaired *t*-test was used for the between-group analysis of the data with equal variances across the samples at the baseline and after the intervention. Welch's unpaired *t*-test was used for the between-group analysis of the data with unequal variances across the samples (i.e. for which data transformation was not helpful) at baseline and post-intervention. *P*-values of less than 0.05 were considered statistically significant. The mean difference and 95% confidence interval were calculated. Percentage changes in the outcome measures were also calculated. Social Science Statistics and GraphPad software programs were used for the statistical analyses.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of Scientific Research of the Faculty of Physical Therapy, Cairo University (approval No.: P.T. REC/012/003204). Clinical trial registered in ClinicalTrials.gov, ID: NCT04562857. URL: https://clinicaltrials.gov/ct2/show/NCT04562857.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

At baseline

The baseline anthropometric and demographic characteristics of the patients in the two groups are shown in Table 1. At the baseline, there were significant differences in the means of total sleep duration, light sleep duration, sleep fragmentation index, and cut points; as well as non-significant differ-

Table 1. Baseline characteristics

Variables		Group A (OSA group) (n_1 = 9)	Group B (mixed SA group) (n_2 = 9)
Age (years)		52.89 ± 7.37	54.33 ± 6.89
Sex	males	6 (66.7%)	5 (55.6%)
	females	3 (33.3%)	4 (44.4%)
BMI (kg/m^2)		30.67 ± 2.31	28.08 ± 1.41**
Smoking history		3 (33.3%)	0 (0%)

Data are expressed as means ± *SD* and as frequency (percentage distribution).
BMI – body mass index
** significant *p*-value based on unpaired *t*-test

Table 2. Outcome measures in the two groups before and after the intervention

Variables			Group A (OSA group) (n_1 = 9)	Group B (mixed SA group) (n_2 = 9)	Group A versus B	
					p-value	mean difference, 95% CI
Sleep parameters from the actigraphy	sleep latency (min)	baseline	90.56 ± 33.02	86.67 ± 35.00	0.811	3.89, [–30.11, 37.89]
		post	20.56 ± 17.76	81.67 ± 50.62	0.001**	61.11, [23.20, 99.01]
		Δ	–70.00 ± 33.63	–5.00 ± 26.22	< 0.001**	65, [34.87, 95.13]
		p-value	< 0.001*	0.583		
	total sleep duration (hours)	baseline	4.94 ± 1.57	2.97 ± 0.61	0.005‡	1.97, [0.77, 3.16]
		post	7.11 ± 2.20	3.61 ± 0.99	< 0.001**	3.5, [1.79, 5.20]
		Δ	2.17 ± 1.39	0.63 ± 1.26	0.026**	1.54, [0.21, 2.86]
		p-value	0.001*	0.171		
	deep sleep duration (hours)	baseline	1.0 ± 0.55	1.11±0.48	0.658	0.11, [–0.40, 0.62]
		post	4.66 ± 1.58	1.58 ± 0.94	< 0.001**	3.08, [1.78, 4.37]
		Δ	3.66 ± 1.14	0.48 ± 1.13	< 0.001**	3.18, [2.04, 4.31]
		p-value	< 0.001*	0.240		
	light sleep duration (hours)	baseline	3.50 ± 1.25	1.86 ± 0.48	0.004‡	1.64, [0.69, 2.58]
		post	1.55 ± 0.46	1.92 ± 0.43	0.104	0.37, [–0.075, 0.815]
		Δ	–1.94 ± 1.26	0.06 ± 0.74	< 0.001**	2, [0.96, 3.03]
		p-value	0.001*	0.827		
	sleep efficiency (%)	baseline	39.89 ± 19.38	11.89 ± 34.57	0.050	28, [–0.005, 56.00]
		post	78.78 ± 14.80	21.11± 25.15	< 0.001**	57.67, [37.04, 78.29]
		Δ	38.89 ± 11.36	9.22 ± 17.62	< 0.001**	29.67, [14.85, 44.48]
		p-value	< 0.001*	0.155		
	sleep fragmentation index	baseline	28.54 ± 12.14	56.67 ± 19.81	0.002**	28.13, [11.71, 44.54]
		post	9.38 ± 4.64	33.73 ± 25.72	0.023‡	24.35, [5.88, 42.81]
		Δ	–19.15 ± 10.84	–22.93 ± 38.34	0.782	3.78, [–24.37, 31.93]
		p-value	0.001*	0.110		
	cut points	baseline	47.22 ± 11.91	62.67 ± 11.30	0.012**	15.45, [3.84, 27.05]
		post	126.44 ± 27.27	78.89 ± 12.46	< 0.001**	47.55, [26.36, 68.73]
		Δ	79.22 ± 20.44	16.22 ± 15.46	< 0.001**	63, [44.89, 81.10]
		p-value	< 0.001*	0.013*		
Overall sleep quality rating item of PSQI (score 0–3; lower score is better)		baseline	2.11 ± 0.78	2.33 ± 0.71	0.536	0.22, [–0.52, 0.96]
		post	0.89 ± 0.93	2.11 ± 0.78	0.008**	1.22, [0.36, 2.07]
		Δ	–1.22 ± 0.44	–0.22 ± 0.67	0.001**	1, [0.43, 1.56]
		p-value	< 0.001*	0.346		
6-minute walk distance (m)		baseline	85.67 ± 36.03	144.44 ± 105.08	0.146	58.77, [–19.72, 137.26]
		post	454.11 ± 12.63	360.78 ± 136.61	0.075	93.33, [–3.61, 190.27]
		Δ	368.44 ± 44.48	216.33 ± 126.29	0.008‡	152.11, [57.49, 246.72]
		p-value	< 0.001*	0.001*		

Data are expressed as means ± *SD*
CI – confidence interval, Δ – absolute change in the mean value from baseline, PSQI – Pittsburgh Sleep Quality Index
***** significant *p*-value of < 0.05 based on the paired *t*-test; ****** significant *p*-value of < 0.05 based on the unpaired *t*-test,
‡ significant *p*-value of < 0.05 based on Welch's unpaired *t*-test

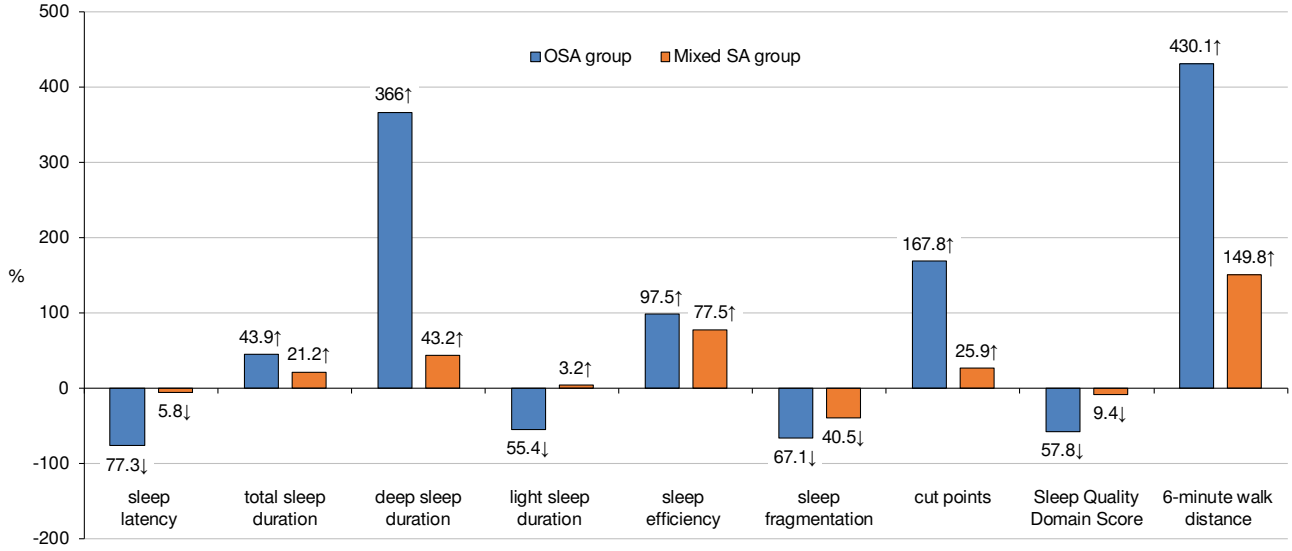

Figure 2. Percentage changes in the outcome measures

ences in the mean values of sleep latency, deep sleep duration, sleep efficiency, overall sleep quality rating item of PSQI, and 6-MWD between the two groups, as shown in Table 2.

After the intervention

There were significant improvements in all outcome measures compared to the baseline in group A ($p < 0.05$) and in only two outcomes (i.e. cut points & 6-MWD) in group B compared to the baseline ($p < 0.05$), as shown in Table 2. Upon comparison between the two groups, there were significant differences between the two groups in the mean values of sleep latency, deep sleep duration, sleep efficiency, and overall sleep quality rating item of PSQI ($p < 0.05$) in favour of group A, as shown in Table 2. Also, there were significant differences between the two groups in the absolute mean changes from the baseline (Δ) of all outcomes ($p < 0.05$) in favour of group A, except for the sleep fragmentation index, as shown in Table 2. Mean differences and 95% confidence intervals for the outcome measures are shown in Table 2. The percentage changes in the outcome measures in the two groups post-intervention are displayed in Figure 2.

Discussion

The incidence of sleep-disordered breathing is common in atrial fibrillation (AF). Exercise-based intervention studies showed a key role of exercise in the management of cardiac patients with coexisting sleep apnoea [12–15]. As an extension of the available literature, we conducted this study. To our knowledge, this is the first study to assess the different effects of moderate-intensity interval training (MIIT) on sleep quality and functional capacity in AF patients with obstructive sleep apnoea and mixed sleep apnoea. Our study showed that a 10-week MIIT, in combination with medical treatment (i.e., CPAP and drug therapy), resulted in significantly greater absolute mean changes from baseline (Δ) in sleep quality indices as measured by actigraphy, in the overall sleep quality rating domain of PSQI, and in the functional capacity measured by the 6-MWT, in AF patients with obstructive sleep apnoea than in AF patients with a mixed sleep apnoea.

Solid evidence supports the clinical benefits of exercise in patients with obstructive sleep apnoea (OSA) [28, 29]. A recent meta-analysis showed that aerobic exercises reduced the severity of sleep apnoea, enhanced sleep quality, and reduced daytime sleepiness in patients with OSA [29]. Only four weeks of moderate-intensity aerobic exercises have successfully reduced the severity of sleep apnoea in patients with coronary artery disease and OSA [14]. Additionally, in a large population-based study by Hall et al. [30], an increased physical activity level was associated with a decreased prevalence of OSA. Our findings regarding the greater improvements in sleep quality indices and functional capacity in the OSA group align with the results from previous studies [13, 31–33]. Ueno et al. [13] showed that a 4-month exercise training programme significantly improved sleep quality and functional capacity in patients with heart failure and OSA. Also, Sengul et al. [31] found that a 12-week aerobic exercise programme significantly improved sleep quality and functional capacity in patients with OSA compared to baseline values. More recently, another study showed that 30–40 minutes of continuous aerobic exercise followed by 10 minutes of strengthening exercises for six months improved sleep parameters in patients with obstructive sleep apnoea compared to the control group [32]. Furthermore, Yang et al. [33] found that a 12-week aerobic exercise programme improved functional capacity in OSA patients. Although our patient population and exercise protocol/duration differed from the above-listed studies, our results generally align with their results.

It is worth noting that although we did not measure OSA severity in the present study, we assume that the greater improvements in sleep quality and functional capacity found in the OSA group may have resulted from reduced severity of the OSA following the exercise intervention. This assumption could be supported by previous studies reporting significant improvements in the severity of OSA following exercise training [14,29,34] and by potential mechanisms based on exercise-induced physiological adaptations that can revert the underlying pathophysiology of OSA, as follows:

(a) Exercise-induced weight loss: The reduction of body weight or abdominal fatness related to the reduced severity of OSA, and a 10% reduction of body mass index associated with a 30% reduction in the apnoea-hypopnoea index (AHI) [35]. Weight loss improves OSA, most likely by reducing oropharyngeal fat deposition and increasing the diameter of the airway [36].

(b) Exercise-induced increased tone and resistance to fatigue of the upper airway dilator muscles: This may act as a stabiliser against pharyngeal collapse, resulting in an increase in the diameter of the upper airway and reduced resistance to airflow during sleep [36–38].

(c) Exercise-induced reduction of fluid retention in the neck: the recumbent position during sleep contributes to fluid shifting from the legs to the neck region, particularly in sedentary or non-ambulatory subjects with reduced lower limb muscle pump and in patients with cardiovascular disease, which can result in laryngeal compression [37,38]. Exercise can reduce the nocturnal fluid shift towards the neck, resulting in an increase in the cross-sectional area and/or dilatation of the upper airways during sleep [14, 38].

(d) Exercise-induced anti-inflammatory response: Patients with OSA show increased levels of C-reactive protein, tumour necrosis factor, and interleukin-6 independently of obesity, and this was associated with daytime sleepiness and fatigue [39]. Regular exercise can reduce these inflammatory markers [39].

(e) Exercise-induced increase in the period of deep sleep or slow-wave sleep: Exercise elevates body temperature, and therefore, could facilitate sleep onset by stimulating heat dissipation and hypothalamus-controlled sleep-inducing mechanisms [37].

The present study also showed that MIIT improved functional capacity in the mixed sleep apnoea group without improving sleep quality. Yamamoto et al. [12] showed that performing aerobic exercises for six months increased the functional capacity in patients with chronic heart failure and central sleep apnoea. Another study by Ueno et al. [13] showed that a 4-month aerobic exercise training programme led to significant improvement in functional capacity in patients with heart failure and central sleep apnoea independent of any improvement in the severity of sleep apnoea. Finally, our findings may have beneficial clinical implications showing that MIIT, in combination with medical treatment, could play a pivotal role in alleviating poor sleep and reducing daytime fatigue or physical activity intolerance associated with obstructive sleep apnoea. Therefore, this could be a part of the management plan for AF patients with OSA.

Limitations

As with most studies, this study has several limitations. The main limitations of this study were the lack of a control group and the small sample size owing to the unavailability of patients. These could hinder the generalisability of our findings. Other limitations include a lack of assessment of the OSA severity and weight loss in response to exercise intervention. Nevertheless, this study has several strengths, such as the use of actigraphy as a non-invasive objective method for assessing sleep-wake rhythms in the natural sleep setting of the patient. Also, this is the first study to compare MIIT-induced changes in sleep quality and functional capacity in AF patients with two presentations of sleep apnoea. Another strength is that it assessed the effects of MIIT on the outcomes most affected by sleep apnoea. Finally, we recommend that future studies investigate the impact of physical exercise, especially MIIT, in combination with medical treatment on the severity/control of sleep apnoea in patients with AF and sleep apnoea.

Conclusions

Complementary to medical treatment, moderate-intensity interval training (MIIT) could significantly improve sleep quality and functional capacity in AF patients with OSA to a better extent than in AF patients with mixed-type sleep apnoea post-CABG surgery. Nevertheless, the latter patient cohort could also benefit from MIIT by enhancing the functional capacity independent of sleep quality. Future studies with a larger sample size are warranted to confirm these findings.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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