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Sleep quality and ventilatory efficiency in elderly heart failure patients: a pilot study on the short-term effect of 4-week low-intensity aerobic exercise

Background Sleep disturbance and ventilator inefficiency are considered two of the most critical complications for general human wellbeing, particularly in elderly heart failure (HF) patients. Studies examining the effect of low-intensity aerobic exercise in the treatment of sleep disturbance and ventilatory inefficiency in this population of patients are limited.

Objective The purpose of the current pilot study was to check the effect of low-intensity aerobic exercise on the quality of sleep and ventilatory efficiency in elderly HF patients.

Materials and methods Design: pilot study. Setting: outpatient physical therapy clinic within Cairo University regional hospital. Participants: eight elderly HF patients (6 men, 2 women) with a mean age of 69.4±4.2 years. Intervention: participants were recruited for a low-intensity exercise program (40 to 50% of maximum heart rate for 30-40 minutes), five sessions weekly for four weeks. Exercise intensity was monitored during the sessions using heart rate. Outcome Measure: sleep quality was assessed pre- and post- four weeks of exercise program usingthe Pittsburgh sleep quality index (PSQI) and ventilatory efficiency was assessed using cardiopulmonary exercise test.

Results HF patients (II–III NYHA), mean age 69.4±4.2 years, body mass index 23.7±2.7 kg/m^2, ejection fraction 32.7±4.5 %, VO_{2peak} 16.27±4.2 ml/kg/min, VE/VCO_2 30.81±12.7. The mean of global PSQI score ranged between 8.2 to 11.4 with a mean of 9.7±3.4 which indicates that the participants experienced sleep disturbance. The post-exercise assessment showed that patients have reported a significant improvement of all PSQI domains compared with baseline assessment ($p<0.05$). VO_{2peak} significantly increased from 16.27±4.2 pre-intervention to 20.03±2.6 ml/kg/min post-intervention ($p=0.049$) whereas VE/VCO_2 slightly decreased with a non-significant difference at the end of the study program ($p=0.594$) indicating animprovement of ventilator efficiencyand overall cardiorespiratory fitness.

Conclusion Short-term application of low-intensity aerobic exercise (4 weeks) may improve the quality of sleep and ventilator efficiency in elderly HF patients. The study findings encourage elderly HF patients with sleep disturbance to adhere to the exercise training program. Also, cardiac rehabilitation programs with low intensity of aerobic exercise should be proposed to these patients by their health care provider.

Keywords Heart failure; elderly; low-intensity aerobic exercise; sleep quality; PSQI

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Introduction

Sleep is considered as one of the most critical components of general human well-being, particularly in elderly population. Sleep disturbance and insufficient sleep quality are extreme complications, which are reported to occur in thirty-nine to seventy-five percent of elderly people [1, 2]. A previous epidemiological study proved that most of older people complain about disturbance in sleep, which is commencing or continuing [2].

Heart failure (HF) was lately observed in huge number of populations causing hospital admission [3], disturbance of life quality and several complications [3–5]. The widespread outcome of HF is the poor sleep quality [4, 5] which extended to further symptoms including fatigue, pain, anxiety, gastrointestinal distress, and depression [5].

One-third (30%) of HF patients with sleep problems at discharge experienced persistent sleep problems at 1-year follow-up and 14% patients without sleep problems at baseline reported sleep problems after 1 year [6]. HF patients are suffering from sleep disturbance due to many issues such as β-blockers medications, sleep apnea, night dyspnea and some comorbidities including chronic obstructive pulmonary disease [7].

Sleep is an essential component of human life and affects profound development and functioning of the brain, cognitive functions, body growth, and psychological conditions. Consequently, sleep disturbance is negatively correlated with physical function, psychological condition and life well-being [8]. Sleep problems such as abnormal sleepiness pattern and chronic poor sleepiness result in increasing mortality and morbidity rate of cardiac disorders [9]. HF patients experienced psychological and physical dysfunctions as a result of sleep disturbance [6, 10]. So, HF patients who experienced sleep disturbances have to be examined and treated with additional attention to avoid unfortunate effects.

Commonly, ventilatory inefficiency is a decisive diagnostic indicator of HF patients. It is usually investigated through measurement of the minute ventilation/carbon dioxide production (VE/VCO_2) slope [11]. HF patients are suffering from a heightened VE/VCO_2 slope which combined with dyspnea and lack of functional capacity [12].

Recently, many studies demonstrated the useful outcomes of exercise training on depression status [13–15], ventilatory markers [16], quality of life [17], and self-efficacy [18] in HF patients and asthmatics [19] whereas studies which examined the low-intensity exercise training effect on the sleep quality and ventilatory efficiency in HF subjects are limited. Consequently, the purpose of the current pilot study was to evaluate the effectiveness of low-intensity aerobic exercise on the sleep disturbance and ventilatory inefficiency in elderly HF patients.

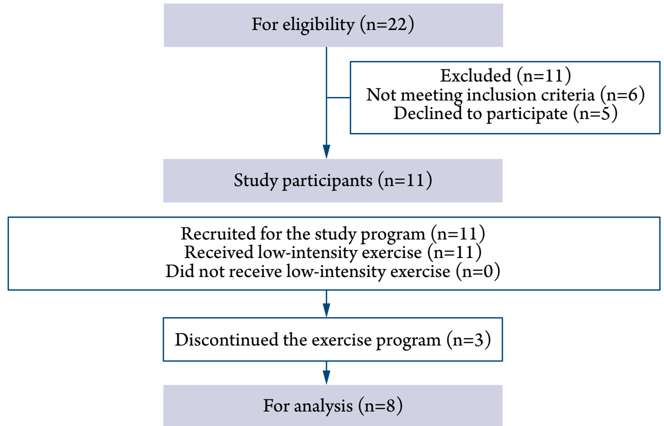
Materials and methods

Subjects

Participants were enrolled through Cairo University regional hospital at outpatient physical therapy clinic between June and September 2018. The patients were eligible to participate in the study if they: 1) were functionally classified as having II and III HF with reference to New York Heart Association (NYHA) classification according to the limitations which endure physical activities, 2) were suffering from obstructive sleep apnea, 3) age more than 65 years, 4) rest ejection fraction (EF) less than 40%, 5) maximum oxygen uptake less than 20 mL/kg/min, 6) no mental or physical disability; 7) stable for a one-month minimum with proper medical control.

Twenty-two elderly HF patients experiencing obstructive sleep apnea were referred by their cardiologists for exercise rehabilitation program. Six patients did not meet the inclusive criteria, and five declined to contribute in the study program. No refusing reasons were reported. Eleven patients (8 men and 3 women) participated in the study. Two men and one woman withdrew during the study program without any registered reason. The flowchart of the study is described in Figure 1. A written informed consent was provided by each patient before intervention. This study protocol was proved by research ethics committee of physiotherapy department [PTA/018/023] based on ethical principles of medical research and Declaration of Helsinki 1964.

Figure 1. The flowchart of the study



Sleep quality assessment

All HF patients were assessed for sleep quality pre- and post- study program using validated and reliable Pittsburgh sleep quality index (PSQI) [20]. This index is 19-item scale consisting of 7 domains: sleep quality, sleep latency, sleep duration, sleep disturbances, sleep habitual efficiency, sleep medications, and daytime dysfunction. The rate of each item is scaled 0–3. 0 reveals no sleep difficulties and 3 reveals severe sleep difficulties. Global PSQI was estimated, scoring from 0 to 21. High scores of global PSQI indicate bad sleep quality while lower scores indicate good sleep quality.

Ventilatory efficiency assessment

Maximum oxygen uptake (VO_{2peak}) and VE/VCO_2 slope were assessed pre- and post- study program through cardiopulmonary exercise test using an electronic braked ergometric cycle (Monark, 939 Novo, USA).

Low intensity aerobic exercise protocol

The data of all patients were obtained using a self-report questionnaire before the intervention and reviewed by a family member or primary caregiver. The definition and purpose of the low-intensity aerobic exercise program were clearly explained for each participant. All patients fulfilled a supervised program of low-intensity aerobic exercise five sessions weekly for 4-week. Each exercise session was commenced with 5 min warm-up and finished with cool-down for 5 min. Each

Table 1. Demographic data and clinical characteristics of the study participants

Variables	Values
Age, years	69.4±4.2
Gender, n (%)	
Men	6(75)
Women	2(25)
Body mass index,Kg/m^2	23.7±2.7
Hemodynamic measures	
Rest HR,beats/min	82.5±17.2
Rest systolic BP,mm Hg	129.6±13.5
Rest diastolic BP,mm Hg	83.7±8.4
Smoking,yes/no	(3/5)
Marital status, n (%)	
Married	6 (75)
Single	2 (25)
Level of education, n (%)	
Literate	1 (12.5)
Primary education	3 (37.5)
High education and above	4 (50)
Heart failure NYHA classes, n (%)	
Class II	5 (62.5)
Class III	3 (37.5)
Etiology, n (%)	
Ischemia	6 (75)
Non-ischemia	2 (25)
Medications, n (%)	
β-blocker	7 (87.5)
AC enzyme inhibitor	8 (100)
Diuretic	6 (75)
Nitrate	3 (37.5)
Digitalis	5 (62.5)
Anticoagulant	8 (100)
EF, %	32.7±4.5
VO_{2peak}, (mL/min^{-1}/kg^{-1})	16.27±4.2
VE/VCO_2 slope	30.81±12.7

HR, heart rate; BP, blood pressure; BMI, body mass index; AC, Angiotensin-converting; EF, ejection fraction; VO_{2peak}, maximal oxygen uptake; VE/VCO_2, minute ventilation / carbon dioxide production.

patient was supervised by an experienced therapist to conduct a 4-week treadmill walking exercise at 40 to 50% of maximum heart rate for 20–30 minutes, five sessions per week.

Statistical analysis

Data were analyzed using windows software of the Statistical Package for the Social Sciences (Version 25, IBM Corp., Armonk, NY, USA). Data were assessed for normality using the Shapiro-Wilk test. Data were described as means ± standard deviations. Descriptive statistics were performed for demographic data and baseline characteristics of the participants. Categorical data were analyzed using chi-square test while the continuous data were analyzed using paired t-test to assess the differences between pre- and post-intervention. Wilcoxon signed-rank test was done due to the small number of the study participants to assess the changes between pre- and post-intervention. The significance level was set at $p<0.05$.

Results

Out of 22 patients, 8 elderly HF patients (6 men, 2 women) were statistically analyzed. The demographic data and clinical characteristics of the study subjects involving gender, age, body mass index (BMI), hemodynamics, classes and etiology of HF, EF, VO_{2peak}, and VE/VCO_2were described in Table 1.

The mean of global PSQI score was ranged between 8.2 to 11.4 with a mean of 9.7±3.4 which indicates that the participants experienced sleep disturbance. As presented in Table 2, post-exercise assessment showed that patients have reported significant improvement of all PSQI domains compared with baseline assessment ($p<0.05$).

For ventilatrory efficiency, VO_{2peak} significantly increased from 16.27±4.2 mL/min/kg pre-intervention to 20.03±2.6 mL/min/kg post-intervention ($p=0.049$), whereas VE/VCO_2 slightly decreased with a non-significant difference at the end of the study program ($p=0.594$) as detailed in Table 2.

Table 2. Differences of the mean values between pre and post-intervention

Variables	Pre-intervention	Post-intervention	p-value
VO_{2peak} (mL/min^{-1}/kg^{-1})	16.27±4.2	20.03±2.6	0.049
VE/VCO_2 slope	30.81±12.7	27.64±10.5	0.594
PSQI			
Global score (0-21)	9.7±3.4	4.4±1.6	0.001
Sleep quality (0-3)	1.7±0.6	0.8±0.3	0.002
Sleep latency (0-3)	1.4±0.3	0.5±0.2	0.001
Sleep duration (0-3)	1.2±0.5	0.6±0.2	0.007
Sleep disturbances (0-3)	1.6±0.7	0.8±0.3	0.011
Sleep habitual efficiency (0-3)	1.3±0.3	0.6±0.2	0.001
Sleep medications (0-3)	1.1±0.4	0.4±0.1	0.001
Daytime dysfunction (0-3)	1.4±0.6	0.7±0.3	0.011

Values are mean ± standard deviation. VO_{2peak}, Peak oxygen uptake; VE/VCO_2, relationship between minute ventilation and carbon dioxide production; PSQI, Pittsburg sleep quality index.

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Discussion

Impairment of sleep quality is one of the imperative complications that appeared through physiological changes of aging in human life and HF. With both, aging and HF, unclear alterations are established in sleep cycle and structure. Several researches have demonstrated that sleep disturbance is positively correlated with mental and physical dysfunctions [21, 22]. Therefore, the current pilot study purposed to investigate the influence of low-intensity aerobic training on the quality of the sleep and ventilator efficiency in elderly HF patients. Our study outcomes point toward that four weeks of low-intensity aerobic exercise are efficient in improvement of sleep quality including all domains in elderly HF patients.

Quality of sleep is lowered in most of HF patients. Sixty-three percent of HF patients have experienced impairment of sleepiness [23]. In this experimental study, we have assessed the quality of sleep among HF patients who underwent three weeks of low-intensity aerobic exercise. There were significant changes in quality of sleep between pre- and post-treatment outcomes using PSQI. Recent study demonstrated that program of cardiac rehabilitation has reduced sleep disturbance in patients with heart diseases [24].

Low-intensity aerobic exercise enhanced quality of sleep in thisstudy. Improving self-report of the quality of sleep with aerobic exercise was exhibited in prior studies of older-adults and middle-aged patients with disturbed sleep quality [25]. However, no earlier studies have assessed quality of sleep in elderly HF patients. Gary and Lee have found an improvement in the sleep time and quality of life following an outdoor walking program, although great exposure to the light during outdoor training is an important factor [26].

Also, many researchers have previously reported the improvement of sleep apnea after conduction of training (aerobics or aerobics/resistance exercises) [26–28]. Moreover, these researches have demonstrated an improvement of sympathetic smooth muscle regulation and biomarkers of HF in the exercised subjects. A short-term cohort study of 4-week intensive rehabilitation in cardiac patients showed an improvement of sleep quality, depression status, body weight, and aerobic capacity [29].

Our present study showed a significant improvement of VO_{2peak} and non-slight improvement of VE/VCO_2 with no significant changes at the end of the 4-week intervention. In agreement with our findings, a previous study demonstrated that aerobic exercise training improves functional capacity and has a positive prognosis in HF patients [30], and recent systematic review found no significant changes in VE/VCO_2 [31], while prior studies proved that high-intensity exercise training may improve VE/VCO_2 in HF patients [32, 33]. We observed a slight decrease of VE/VCO_2 regarding the beneficial effects of regular aerobic exercise in the improvement of ventilatory efficiency in HF patients. Also, we recommend the evaluation of the long-term impact of aerobic exercise on ventilatory efficiency in elderly HF patients.

Study limitations

Some limitations were determined in our study. The limited number of the study participants and the short duration of the study indicate non-generalization about the effects of the exercise program. Also, the included HF patients may not be representative for other patients comprised in future studies. Furthermore, the sleep quality was assessed subjectively using PSQI while the objective assessment is available by using easy and cheap actigraphy which record sleep/wake cycles in the home settings. In addition, further studies should include larger sample size and longer duration of exercise intervention.

Conclusions

Short-term of low-intensity aerobic exercise (4 weeks) may improve the quality of sleep and ventilatory efficiency in elderly HF patients. The study findings encourage elderly HF patients with sleep disturbance to adhere to exercise intervention and motivate physician's referral to the cardiac rehabilitation program.

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List of abbreviations

NYHA: New York Heart Association. EF: Ejection Fraction. HF: Heart Failure. PSQI: Pittsburgh sleep quality index. BMI: Body Mass Index. VO_{2peak}: Maximum Oxygen Uptake.

No conflict of interest is reported.

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