Influence of pulmonary rehabilitation on the sleep patterns of patients with chronic obstructive pulmonary disease*

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Background: Pulmonary Rehabilitation (PR) improves the quality of life of chronic obstructive pulmonary disease (COPD) patients. However, the influence of PR on the sleep pattern of these patients is unknown.

Objective: To evaluate the influence of PR on the sleep patterns of patients with COPD.

Method: A total of 27 patients (22 men/5 women) were submitted to polysomnographic, gasometric and anthropometric studies before and after six weeks of PR and were evaluated using the Epworth Sleepiness Scale. The results were analyzed using paired Student's *t*-test, ANOVA and Newman-Keuls multiple comparison test.

Results: Mean age was 63.3 ± 5.3 years, mean FEV_1 was 54.8 ± 25.4% of predicted, mean FEV_1/FVC was 49.9 ± 12.0% of predicted, mean resting PaO_2 was 69.7 ± 7.3 mmHg, and mean resting SaO_2 was 93.7 ± 2.1%. Polysomnography revealed sleep patterns to be fragmented, with frequent waking and reduced slow-wave sleep, as well as oxygen desaturation. The most significant drops in oxygen saturation occurred during rapid eye movement sleep. No significant differences were observed between pre- and post-PR values for the other variables studied ($p > 0.05$).

Conclusion: In the group of patients studied, PR did not alter sleep patterns.

Key words: Sleep. Pulmonary Disease. Chronic Obstructive. Lung Diseases, rehabilitation.

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INTRODUCTION

Depending on the type of exercise, duration, time of day performed and frequency, physical activity may influence sleep in healthy individuals[1,2]. In a meta-analysis study[1], it was reported that acute and chronic physical exercise resulted in increases in delta sleep (stages 3 and 4) and total sleep time (TST) and decreases in sleep latency and rapid eye movement (REM) sleep.

King et al. [3] evaluated the effect of 16 weeks of moderately-intense exercise on 67 individuals aged 50 to 76 who were sedentary and reported moderate sleep complaints: either awakening during the night or having difficulty in going to sleep. The authors demonstrated that, after the program, the quality of sleep improved for these individuals. In addition, it has been shown that, although there is a correlation between arterial oxygen saturation (SpO_2) during sleep and physical exercise[7,8], a decrease in oxygen saturation is not predictive of nocturnal oxygen desaturation, since a slight decrease in SpO_2 during physical activity does not rule out a more dramatic decrease in oxygen saturation during the night[7,9].

On the other hand, studies have shown that, in the case of patients diagnosed with chronic obstructive pulmonary disease (COPD), nocturnal hypoxemia and hypercapnia are closely related to periods of REM sleep[4,5]. The lowest nocturnal SpO_2 levels have been found in patients presenting more severe diurnal hypoxemia and longer REM sleep periods[6].

In addition to gas exchange alterations, patients diagnosed with COPD present other changes in the quality of sleep[10,11]. Since sleep tends to be fragmented by frequent awakenings, there is a decrease in delta and REM sleep[12], as well as a decrease in TST and a greater number of sleep-stage changes[14,15]. However, sleep disturbance is frequently ignored by most physicians in the evaluation of patients diagnosed with COPD, even in study protocols designed to evaluate the quality of life of these patients[12].

Although there have been many studies of COPD patient sleep patterns, the relationship between pulmonary rehabilitation (PR) and the sleep patterns of these patients has not yet been studied. Therefore, the objective of the present study was to determine the influence of PR on the sleep patterns of patients with COPD.

Abbreviations used in this paper:

AI	– Awakening index
AHI	– Apnea-hypopnea index
BMI	– Body mass index
COPD	– Chronic obstructive pulmonary disease
FEV_1	– Forced expiratory volume in one second
FVC	– Forced vital capacity
NREM	– Non-rapid eye movement
OSAS	– Obstructive sleep apnea syndrome
$PaCO_2$	– Arterial carbon dioxide tension
PaO_2	– Arterial oxygen tension
PR	– Pulmonary rehabilitation
REM	– Rapid eye movement
SaO_2	– Arterial oxygen saturation
SpO_2	– Arterial oxygen saturation
TST	– Total sleep time

METHOD

In a non-randomized, open clinical trial, 35 patients with COPD were evaluated. Of those, 8 patients were excluded: 3 for presenting obstructive sleep apnea syndrome (OSAS), 2 for refusing to be submitted to a repeat polysomnography following PR, 1 for developing an orthopedic problem during training sessions, 1 for presenting severe arrhythmia during the program, and 1 for presenting uncontrolled arterial hypertension. Therefore, the study sample consisted of 27 patients: 22 males and 5 females. The study period was from August 2001 to April 2003. Diagnosis of COPD was made in accordance to the criteria defined by The Global Initiative for Chronic Obstructive Lung Disease[16]. An apnea-hypopnea index (AHI) greater than 5 per hour of sleep was the criteria used for classifying patients as suffering from OSAS[17].

This study included patients with clinically stable COPD who were former smokers (smoke-free for at least 3 months). Patients were excluded if they presented OSAS, cardiovascular or orthopedic diseases that would prevent them from performing the exercises proposed in the PR protocol, or other comorbidities that would put them at risk during exercise.

The Ethics Research Committee of the Hospital Universitário de Brasilia approved the study. All patients gave written informed consent.

Patients were submitted to spirometric, blood gas, anthropometric and polysomnographic analysis. The Epworth Sleepiness Scale was also used. All analyses were made both prior to and immediately after PR.

Pulmonary function: absolute values of forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and FEV_1/FVC ratio were measured (Vmax−22 series spirometer; Sensor Medics, Yorba Linda, CA, USA). Relative predictive values based on gender, age and height were calculated considering the values described by Knudson et al.[18] Spirometry tests were performed in accordance with the guidelines established by the American Thoracic Society[19].

Arterial blood gas analysis: Values were determined for arterial oxygen tension (PaO_2), arterial carbon dioxide tension ($PaCO_2$) and arterial oxygen saturation (SaO_2) using a Ciba Corning 278 Gas System (Ciba Corning, Diagnostics Corp., Medfield, MA, USA).

Anthropometry: Body mass index (BMI) was calculated using the formula: weight/height^2 (kg/m^2). Neck circumference (cm) was measured above the cricoid cartilage.

All-night polysomnography: Parameters were monitored using electroencephalography, electrocardiography, electromyography, electroculography and nasal/oral airflow thermistry, as well as by recording body position, snoring, ribcage/abdominal movement and arterial oxygen saturation (SpO_2). These measurements were taken using an Alice 3® digital polysomnographic system (Healthdyne Technologies, Marietta, GA, USA). Traditional polysomnographic variables were also evaluated in accordance with the Rechtschaffen & Kales method[20]. We also included the awakening index (AI), which is the number of awakenings divided by sleep period time and multiplied by 60, thus representing the number of awakenings per hour of sleep.

Epworth Sleepiness Scale: Prior to and following the PR program, all patients completed the sleepiness scale questionnaire created by Johns[21].

Physical practice: The PR program consisted of three (morning) sessions a week for 6 weeks. Each PR program exercise session was conducted in accordance with the guidelines devised by Rodrigues et al.[22] The effect of PR on patients was evaluated using the 6-minute walk test and incremental exercise tests involving the upper extremities.

Statistics: Values of the studied variables are presented as means ± standard deviation (SD). Paired Student's *t*-test was used for the comparison of variables prior to and following the PR program. Differences between SpO_2 levels during nocturnal vigilance, non-REM (NREM) sleep, and REM sleep were analyzed using ANOVA and Newman-Keuls multiple comparison test. Values of $p < 0.05$ were considered statistically significant.

RESULTS

The mean age of the patients studied was 63.3 ± 5.3, ranging from 54 to 72.

Values for spirometric, blood gas analysis and anthropometric variables prior to and following the PR program are shown in Table 1. There were no statistically significant differences among these variables ($p > 0.05$).

Polysomnography revealed fragmented sleep patterns, reduced delta sleep and less hemoglobin desaturation. Prior to PR, SpO_2 during REM sleep

TABLE 1
Spirometric, gas exchange, anthropometric and Epworth sleepiness scale values of patients with COPD before and after the PR program

	Before PR	After PR
FVC (%)	85.0 ± 26.6	87.4 ± 22.5
FEV_1 (%)	54.8 ± 25.4	55.0 ± 22.5
FEV_1/FVC (%)	49.9 ± 12.0	49.5 ± 12.4
PaO_2 (mmHg)	69.7 ± 7.3	71 ± 8.7
$PaCO_2$ (mmHg)	35.0 ± 4.8	34.7 ± 4.6
Daytime SpO_2 (%)	93.7 ± 2.1	93.7 ± 2.2
BMI (kg/m^2)	24.6 ± 4.2	24.6 ± 4.1
Neck circumference (cm)	37.5 ± 3.7	37.9 ± 3.7
Epworth sleepiness scale	9 ± 4	9 ± 4

FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; PaO_2: arterial oxygen tension; $PaCO_2$: arterial carbon dioxide tension; BMI: body mass index; SpO_2: arterial oxygen saturation

was significantly lower (88 ± 4.2%) than during nocturnal vigilance (90 ± 2.9%) or NREM sleep (89.4 ± 3.3%) ($p < 0.05$). In turn, SpO_2 during NREM sleep was significantly lower than during nocturnal vigilance ($p < 0.05$) (Fig. 1).

There was no statistically significant difference between polysomnographic variables and daytime drowsiness measured prior to and following PR ($p > 0.05$) (Table 2).

As for PR, there was a significant increase in the distance covered in the 6-minute walk test as well as in the maximum load achieved in the incremental exercise test of the upper extremities ($p < 0.05$).

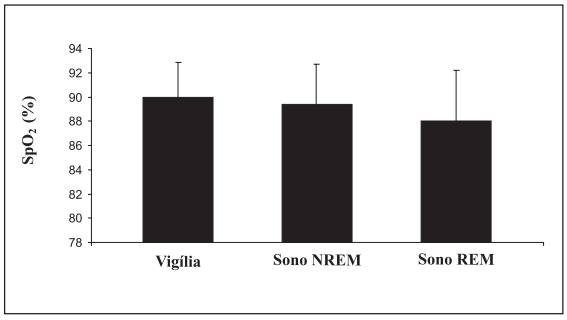

Figure 1 – Comparison of SpO2 values during nocturnal vigilance and during sleep

DISCUSSION

The design of the present study made it possible to characterize the sleep patterns of patients with COPD. When we compared the sleep patterns of the patients in the present study with those of healthy adults[23], we realized that sleep patterns of patients with COPD were fragmented, characterized by increased vigilance throughout the entire sleep period and by frequent awakenings. We also noticed that sleep was inefficient, and that it was difficult for patients to fall asleep (increased sleep onset latency and REM sleep) and to move into deeper sleep stages (increased percentages of stage 1 NREM sleep and decreased percentages of delta sleep). These data are in accordance with results reported by other authors[12-15].

In a review article, George[24] called attention to insomnia in patients with COPD, corroborating the high incidence of awakenings and the difficulty in falling asleep observed in the present study.

TABLE 2
Polysomnographic values for patients with COPD before and after the PR program.

	Prior to PR	After PR
AHI (events/hour)	2.3 ± 3.9	2.8 ± 5.2
Snoring period (minutes)	10.9 ± 9.1	9.8 ± 7.3
Registration period (minutes)	486.4 ± 46.0	483.2 ± 32.4
TSP (minutes)	441.9 ± 67.1	442.7 ± 39.1
TST (minutes)	321.3 ± 75.8	323.1 ± 69.1
TST/TSP (%)	72.8 ± 13.9	72.7 ± 12.7
Vigilance during TSP (%)	27.2 ± 13.9	27.3 ± 12.7
Sleep latency (minutes)	28.8 ± 28.5	27.3 ± 23.1
REM sleep latency (minutes)	113.9 ± 73.0	105.6 ± 56.3
Stage changes	126.8 ± 35.2	117.1 ± 33.6
Movement episodes	40.1 ± 14.6	37.2 ± 14.3
AI (events/hour)	30.3 ± 10.0	30.9 ± 8.2
Stage 1 (%)	20.7 ± 7.6	19.7 ± 8.8
Stage 2 (%)	49.0 ± 8.3	48.7 ± 9.5
Delta sleep (%)	8.8 ± 4.9	9.5 ± 7.4
REM sleep (%)	19.9 ± 6.4	20.6 ± 7.0
SpO_2 time < 90% (%)	40.1 ± 37.8	45.1 ± 37.2
SpO_2 (%) – mean during vigilance	90.0 ± 2.9	90.6 ± 2.0
SpO_2 (%) – mean during NREM sleep	89.4 ± 3.3	89.7 ± 2.2
SpO_2 (%) – mean during REM sleep	88.0 ± 4.2	87.5 ± 3.6

AHI: apnea-hypopnea index; TSP: total sleep period; TST: total sleep time; REM: rapid eye movement; AI: awakening index; SpO_2: arterial oxygen saturation; NREM: non-rapid eye movement

Some patients diagnosed with COPD present concomitant OSAS. Designated an overlap syndrome, COPD concomitant with OSAS may result in a worsening of nocturnal hypoxemia[10,11]. In our study, 8.6% of the population studied was diagnosed with this syndrome. This figure is similar to that reported by Chaouat et al.[25], who reported that 11% of the 265 COPD patients studied also presented OSAS. It is difficult to evaluate the real association between COPD and OSAS, principally due to two main factors. First, there may be problems in the triage of patients. For example, Guilleminault et al.[26] evaluated patients with COPD who, in most cases, had been referred to the sleep clinic due to excessive daytime sleepiness. These authors reported that 84% of the patients were diagnosed with overlap syndrome. The second factor is the lack of consensus among authors regarding the number of apnea and hypopnea episodes that characterize OSAS[24,27-30].

In review articles, Douglas[11] and McNicholas[31] defined some factors that may be responsible for hypoxemia during sleep in patients diagnosed with COPD. These factors include alveolar hypoventilation, decreased functional residual capacity, and changes in the ventilation/perfusion ratio. Due to the effect of the oxyhemoglobin dissociation curve, patients with hypoxemia present higher desaturation levels in relation to hypoventilation than do patients presenting normoxemia[31].

The present study confirmed data in the literature showing that there is a decrease in SpO_2 during sleep, and that the highest desaturation level is reached during REM sleep in patients with COPD[14,27].

Considering the objectives of the present study, we noticed that, although the 6-week PR program had a positive effect on exercise performance, it had no impact on the polysomnographic data obtained from the 27 patients with COPD. Therefore, our results revealed that COPD patients might respond to exercise differently than do normal individuals, whose quality of sleep improves after performing physical activities[1,3].

Kubitz et al.[1], in a meta-analytic review, reported that both acute exercise (exercising vs. not exercising) and chronic exercise (practitioners vs. non-practitioners, athletes vs. non-athletes) promote increased delta sleep and increased TST, as well as reducing latency of sleep onset and of REM sleep. However, the effect of chronic exercise on sleep is more extensive than that of acute exercise. In addition, long-duration aerobic exercises (unless practiced too close to bedtime) have a greater impact on sleep quality. The studies used in this meta-analysis refer to exercise practiced between 2 pm to 7 pm, of approximately one hour in duration.

According to Horne & Staff[32], there may be an increase in slow-wave sleep whenever there is an increase in body temperature during exercise. However, this hypothesis is debatable, since body temperature decreases to its basal value approximately 2 hours after exercise. Youngstedt et al.[2] concluded that body temperature does not moderate delta sleep after exercise.

One of the factors that might have contributed to the fact that we observed no effect of the PR on the sleep patterns of our patients was the short duration of the program (only 6 weeks) and of the individual sessions (30 minutes each). In studies involving individuals not diagnosed with pulmonary diseases, exercise sessions are typically longer. However, we believe that the principal determinant of higher quality post-exercise sleep in these patients is the time of the day at which the exercises are performed. Driver & Taylor[34] corroborated this hypothesis, stating that when healthy individuals exercise in the morning, independently of intensity or duration, there is probably no effect on their sleep patterns, differently than when they practice exercises late in the afternoon. In addition, all of the studies analyzed in the Kubitz et al.[1] meta-analysis reported on exercises performed in the afternoon or in the evening.

In addition, we must bear in mind that, all these factors that may influence sleep patterns notwithstanding, patients with chronic lung disease may also present chronic hypoxemia. As previously mentioned, hypoxemia may lead to sleep fragmentation. Since PR does not affect this condition, sleep patterns would be expected to remain unchanged.

In light of this, we believe that additional studies involving more prolonged periods of PR, conducted at various times of day for the purpose of comparison, should be carried out.

In summation, we can conclude that PR does not alter sleep patterns of patients with COPD.

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