

Concurrent respiratory resistance training and changes in respiratory muscle strength and sleep in an individual with spinal cord injury: case report

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Context: Quality sleep possesses numerous benefits to normal nighttime and daytime functioning. High-level spinal cord injury (SCI) often impacts the respiratory muscles that can lead to poor respiratory function during sleep and negatively affect sleep quality. The impact of respiratory muscle training (RMT) on sleep quality, as assessed by overnight polysomnography (PSG), is yet to be determined among the spinal cord-injured population. This case report describes the effects of 10 weeks of RMT on the sleep quality of a 38-year-old male with cervical SCI.

Methods: Case report.

Findings/results: The subject completed overnight PSG, respiratory muscle strength assessment, and subjective sleepiness assessment before and after 10 weeks of RMT. The post-test results indicated improvements in sleep quality (e.g. fewer electroencephalographic (EEG) arousals during sleep) and daytime sleepiness scores following RMT.

Conclusion/clinical relevance: Respiratory activity has been proven to impact EEG arousal activity during sleep. Arousals during sleep lead to a fragmented sleeping pattern and affect sleep quality and daytime function. Our subject presented with a typical sleep complaint of snoring and excessive sleepiness. The subject's pre-test PSG demonstrated a large number of arousals during sleep. It is important for all individuals complaining of problems during sleep or daytime problems associated with sleep (i.e. excessive daytime sleepiness) to seek medical attention and proper evaluation.

Keywords: Sleep quality, Respiratory resistance training, Respiratory muscle strength

Introduction

Sleep difficulties, such as problems initiating sleep, problems maintaining sleep, awakenings at night, snoring, and sleep-disordered breathing (SDB), are reported to occur more often among individuals with spinal cord injury (SCI) compared with non-SCI individuals.^{1,2} In addition to the secondary medical problems associated with SCI, problems associated with poor sleep can have a variety of consequences ranging from relatively minor, e.g. fatigue³ and daytime sleepiness,⁴ to severe, e.g. cardiovascular disease⁵ and stroke.⁶ Polysomnography (PSG) is

the gold standard for the assessment of sleep and represents the most objective evaluation currently available. In addition to objective assessment, there are subjective assessments of sleep and daytime sleepiness. One example, the Epworth Sleepiness Scale (ESS) is used to assess sleep propensity and provides an indication of excessive daytime sleepiness (EDS), which may serve as a marker for poor sleep quality.⁷

The respiratory muscles are often impacted by SCI and respiratory muscle training (RMT) may increase strength,^{8,9} endurance,¹⁰ and overall pulmonary function.^{9,11} RMT involves breathing against an inspiratory resistance, an expiratory resistance, or a concurrent inspiratory and expiratory resistance. Concurrent

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inspiratory and expiratory resistance devices generate resistance using either a pressure-threshold or an adjustable orifice. Researchers investigating the use of concurrent pressure-threshold resistance (CPTR) devices have primarily focused on non-SCI individuals.¹²⁻¹⁵

To date, only one study has investigated the changes in sleep parameters following RMT for individuals with SCI. Wang *et al.*¹⁶ studied the use of an inspiratory resistance device on 14 tetraplegia patients; however, the authors used oxygen saturation and end-tidal carbon dioxide (ETCO₂) assessment in lieu of overnight PSG assessment. There is no documentation, case or otherwise, of the effects of CPTR devices on sleep parameters of individuals with SCI. Equally, there is no documentation, case or otherwise, of the effects of CPTR training on sleep parameters as measured by PSG. This case report documents the PSG, ESS, and respiratory muscle strength results before and after 10 weeks of CPTR training for a single subject. The authors sought and received institutional review board approval to investigate this case.

Case report

In this case, we describe pulmonary and sleep assessment findings for an individual with SCI following 10 weeks of RMT with the Powerlung Performer™ (Powerlung Inc., Houston, TX, USA) CPTR device. The subject was required to perform three sets of 10 breathing repetitions three times per day. If able to perform 10 repetitions without experiencing fatigue or lightheadedness, then the resistance for inspiration and expiration was increased by one level. The authors did not witness daily use of the Performer device; therefore, we asked the subject to keep a log documenting daily use and the adjustments. The log was returned at the end of the 10-week period and reviewed. The subject missed a total of 7 days scattered throughout the 10-week period.

At the time of this case, the male subject was 38 years old, 68 inches in height, weighed 171 pounds, and had a body mass index of 26.2. He sustained a complete spinal injury at cervical vertebrae six 19 years prior to this report. The subject presented to us with complaints of snoring, waking up with a dry mouth, frequent leg kicks/twitching, and daytime sleepiness. He indicated no history of cardiac or pulmonary disease on his medical history questionnaire. The sleep history questionnaire revealed sleep hygiene issues (e.g. watching television in bed, variable wake times, etc.), mild snoring in the supine position, occasional dry mouth and nasal congestion in the morning, and a family member who uses continuous positive airway pressure (CPAP) at night. The only medication prescribed at the time of this report was baclofen

(Lioresal®, Novartis Pharmaceuticals, New York, NY, USA) to control muscle spasms. No over-the-counter medications were reported. Prior to each overnight PSG, the subject completed three negative inspiratory force (NIF) maneuvers to assess respiratory muscle strength, and the ESS questionnaire. All NIF maneuvers were completed in accordance with the American Thoracic Society guidelines using a pressure manometer (Instrumentation Industries, Bethel Park, PA, USA). Overnight PSG studies were completed in accordance with the American Academy of Sleep Medicine (AASM) guidelines. Before and after PSG studies were conducted using Compumedics Profusion PSG™ software (Compumedics Limited; Abbotsford, VIC, Australia) with initial evaluation by automatic sleep scoring analysis and follow-up scoring analysis by a registered polysomnographic technologist (RPSGT) not associated with the study.

Results

Table 1 includes PSG information before and after use of the CPTR device. The number of awakenings, the amount of wake after sleep onset (WASO), and the respiratory disturbance index (RDI) during rapid eye movement (REM) sleep all decreased from pre- to post-testing. Sleep efficiency increased from pre- to post-testing. This information indicates an improved

Table 1 Pre-treatment and post-treatment PSG data

	Pre-treatment PSG data	Post-treatment polysomnography data
Total sleep time (hours)	6.42	7.63
Number of awakenings	11	6
WASO (minutes)	20.5	16
Sleep efficiency (%)	91.8	96.6
REM RDI (events/hour)	11.8	4.3

Table 2 Summary of arousal data for the pre-treatment and post-treatment PSG study

Arousal summary	Pre-treatment PSG data	Post-treatment PSG data
Respiratory arousals	104	61
Limb movement arousals	14	7
Spontaneous arousals	40	34
Total number of arousals	158	102
Respiratory arousal index (events/hour)	16.2	8.0
Limb movement arousal index (events/hour)	2.2	0.9
Spontaneous arousal index (events/hour)	6.2	4.5
Total arousal index (events/hour)	24.6	13.4

Table 3 Pulmonary function and subjective sleep assessment data

	Pre-treatment data	Post-treatment data
NIF (cmH ₂ O)	-80 (range: -64 to -80)	-80 (all maneuvers at -80)
ESS	11	9

sleep quality. Table 2 reports the arousal findings associated with this case. All arousal parameters decreased from pre- to post-testing and indicate less fragmented sleep and improved sleep quality. Table 3 displays the NIF and ESS results. There was no change in the single best NIF maneuver recorded from pre-testing to post-testing; however, the range of values narrowed on post-testing.

Discussion

The decrease in number of awakenings and the WASO indicated that this subject spent more time asleep and potentially an improved sleep quality with less sleep fragmentation. The changes in awakenings and WASO could be secondary to the arousal findings. We reported the RDI during REM sleep due to the dramatic change in pre-test versus post-test values. REM sleep is marked by muscle paralysis and further dysfunction of the respiratory system due to SCI could further compromise ventilation specifically during REM. The change in REM RDI following CPTR training could indicate a more stable breathing pattern during this sleep stage.¹⁷ The total sleep RDI remained in the 5–10 events/hour range marking minimal SDB. Our subject did not possess many of the predictors for SDB, i.e. overweight, thick neck, supine sleeping position, and therefore it was not surprising that his overall RDI was low. In addition, respiratory-related arousals during sleep may appear without an accompanying diagnosis of SDB.¹⁸

Different from awakenings, arousals are defined as an abrupt shift in the electroencephalographic (EEG) frequency lasting at least 3 seconds.¹⁹ Arousals may occur in non-rapid eye movement (NREM) and REM sleep. Brief shifts in brain wave activity lead to a fragmented sleeping pattern, and ‘...periodic disturbance[s] of the ongoing EEG during sleep as described by the ASDA [now the AASM] produces numerous physiological and behavioral changes similar to those produced by total sleep deprivation.’ (p. 138)²⁰ Equally, each sleep arousal will result in sympathetic nerve activation thus producing an increase in heart rate and blood pressure.²¹ Therefore, it is conceivable that repeated arousals during sleep, both EEG and autonomic, can have deleterious effects. Respiratory-related arousals accounted for

more than half of all the arousals scored during sleep. Furthermore, there was a 59% decrease in respiratory arousal occurrence from pre-testing to post-testing. Although the single best NIF did not improve after 10 weeks of CPTR, the subject did engage in respiratory-specific exercises and this could have contributed to the improvement in respiratory-related arousals. Sengul *et al.*²² demonstrated an improvement in several sleep parameters following 12 weeks of regular exercise. The number of arousals experienced by our subject and the reduction following CPTR training may warrant further exploration. The true impact of these arousals on sleep is debatable.

Although the subject’s single best NIF did not improve, we believe that the three NIF values at -80 cmH₂O on post-testing indicate a slight improvement in respiratory muscle strength. There are a couple reasons to account for the pre-test versus post-test changes in NIF. First and most important, our subject demonstrated an adequate amount of respiratory muscle strength on pre-testing²³ and this finding would likely contribute to the small change in NIF upon post-testing. We suspect that a greater improvement in NIF would have been achieved if the subject initially recorded a lower value. Contributing to this is the time since injury and the level of injury. A shorter time since injury and a higher cervical injury more than likely will result in a lower pre-test NIF value. Second, the wider range in NIF on pre-testing could indicate a difference in effort and the potential for ‘cheek pressure’ versus true diaphragm pressure on the single best maneuver.

The ESS score decreased slightly from pre- to post-testing. A score greater than 10 indicates EDS and potentially a fragmented sleeping pattern. There is a positive correlation between the ESS and the number of arousals. We were not able to witness a complete reduction in arousals for our subject and this could have contributed to the small change in ESS.

We did not assess ventilatory parameters, i.e. ETCO₂, tidal volume, minute ventilation, etc., during sleep; however, in hindsight doing so may have provided valuable information related to the effects RMT on sleep and breathing. Medication use among the SCI population may also contribute to sleep problems. Antispasticity medication has been implicated in increasing the likelihood of snoring in the obese SCI population.²⁴ Although baclofen use may further complicate a potential sleep dysfunction, the medication most likely did not contribute to the changes discovered from pre-testing to post-testing in this particular case.

Conclusion

We found this case to be interesting because of the uniqueness of the scenario to the available literature as well as the changes in arousal data. We also believe this case is a reminder to the reader of the importance of sleep assessment in the SCI population. It is important to note that the night-to-night variability in sleep is well documented in the sleep literature. Overnight PSG is merely a snapshot of an individual's sleep and results should be interpreted with this understanding. Although many of the variables presented in this case improved following 10 weeks of CPTR use, there is no guarantee the changes are solely the result of the device. A study with a larger number of subjects is warranted to determine the true impact of RMT on sleep and arousal indices. However, a larger study may be difficult in this population. Previous research involving SCI individuals demonstrates that recruitment and attrition difficulties occur when conducting larger trials. Also, subject selection is important. We believe RMT will have the most benefit among SCI individuals that generate a NIF below the lower limit of normal.

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