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# Effects of Resistance Exercise on the Sleep Patterns of Sedentary Individuals

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## Abstract

**Background:** The past decades have seen the conduction of a great number of studies that have attempted to assess the effects of physical exercise on sleep. However, the majority of these studies have specifically evaluated the effects of aerobic exercise. To the best of our knowledge, only one study has evaluated the effects of resistance exercise (RE) on sleep patterns.

**Objective:** The aim of the current investigation is to verify the effect of one session of RE on the sleep patterns of sedentary individuals with good sleep quality.

**Methods:** Twenty-seven sedentary men with good sleep quality between the ages of 20 and 40 participated in this investigation. The experimental protocol consisted of one session of RE, which was comprised of 3 sets of 15 repetitions with a load equivalent to 50% of the one-repetition maximum test (1-RM) with 90 sec intervals between each set. The sleep parameters were analyzed by means of a t-test, with significance defined as $p < 0.05$.

**Results:** No significant differences were found between sleep parameters when RE was performed during different periods of the day. However, the sleep onset latency and the sleep efficiency in the evening group showed a trend toward alteration ($p = 0.06$).

**Conclusion:** Sedentary individuals with good sleep quality did not display significant alterations in their sleep parameters after performing one session of RE with a load equivalent to 50% of 1-RM.

**Keywords:** physical exercise, physical activity, slow-wave sleep, REM sleep, polysomnography.

## Introduction

Physical exercise is commonly accepted to be an important aid in the promotion of sleep (1,2). Epidemiological studies have generally shown positive associations between physical exercise and sleep (3-5). Additionally, exercise is recommended by the American Sleep Disorders Association (6) as a non-pharmacological intervention to improve sleep.

Several decades of research have demonstrated the effects of aerobic exercise (AE) on the quantity and quality of sleep among

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various populations worldwide (6-18).

Previous studies on AE have demonstrated that it is associated with an increase in Total Sleep Time (TST) (14,17), Slow-Wave Sleep (SWS) (6, 8, 9, 14, 15), Rapid Eye Movement (REM) sleep latency (8, 17) and a decrease in Sleep Onset Latency (SOL) (8) and REM sleep (7, 8, 14, 18). In contrast, Oda (13) found no significant differences in sleep parameters after exercise. However, this controversial result may be due to the use of different protocols and methodologies.

Four hours and eight hours prior to bedtime seem to be the periods when sleep parameters can be most affected by exercise (17), possibly because the thermal load produced by exercise can result in a loss of water and an increase in the core body temperature (19).

After an acute session of resistance exercise (RE), the literature suggests that there are alterations in the cardiovascular and endocrine systems, including increased heart rate, blood pressure, cardiac debit, and elevated blood concentrations of growth hormone, beta-endorphins, cortisol and testosterone (20). The chronic effects of these alterations are reflected in an increase in muscle strength and activity, hypertrophy of muscles, tendons, ligaments and bones, and a decrease in fat mass and percent body fat (20). Consequently, such improvement in general physical capacity can be able to promote positive alterations on sleep.

This study was conducted to add to the scarce literature regarding the sizeable and specific population of healthy, sedentary individuals who have no history of sleep disturbances.

Data from this population could point to new lines of research examining how RE affects sleep parameters. This study sought to examine the hypothesis that, like AE, RE might also alter sleep patterns, specifically increasing SWS and TST and decreasing REM sleep because RE is more vigorous than AE.

This investigation was motivated by our previous research assessing the effects of exercise on sleep and sleep disorders (3, 21-23), wherein physical exercise in patients with periodic leg movements (PLMs) reduced this sleep parameter.

## Methods

The present study was approved by the ethics committee for scientific research at the Federal University of Sao Paulo (UNIFESP) (0948/05). We obtained written informed consent from the volunteers who chose to participate in the investigation. Information about the study was disseminated by the media secretary of UNIFESP, resulting in the participation of 47 volunteers. Our group was composed of men between 20 and 40 years of age who were sedentary, featured no abnormalities in a clinical electrocardiogram (ECG) at rest and under physical strain, and who were "good sleepers". We excluded subjects from the investigation who presented values the apnea and hypoapnea index (AHI) > 15 (24), and those who presented PLM > 5 (25), assessed by means of polysomnography (PSG).

### One Repetition Maximum test (1-RM)

The 1-RM test was performed 3 days after subjects had obtained experience working with six devices (whose descriptions follow). The recommendations made by Kraemer et al. (26) were adopted, and the test was carried out at the same time of day and in the same ambience in which the volunteers carried out their session of RE. Room temperature within the laboratory was kept between 21-23°C.

### Resistance Exercise (RE)

The effects of one session of RE on sleep pattern were assessed in the Center of Studies in Psychobiology and Exercise. Each volunteer performed the 1-RM test and a session of RE during only one period of the day (morning, 7:00-9:00h; afternoon, 13:00-15:00h; or evening, 18:00-20:00h). The RE session consisted of the use of six Technogym® devices: chest press (exercising chest muscles), leg press (exercising leg muscles), lat machine (exercising back muscles), leg curl (exercising rear thigh muscles), shoulder press (exercising shoulder muscles) and abdominal crunch (exercising abdominal muscles). The session of RE was composed of 3 sets of 15 repetitions with a load equivalent to 50% of the 1-RM test and 90 sec intervals between the series. The RE session lasted between 40 and 45 minutes.

### Sleep Parameters

Volunteers arrived at the sleep laboratory at 21:30h for electrode attachment and went to bed at 23:00h. Sleep parameters were recorded by means of two PSGs in the laboratory. One was collected prior to the RE session, and the second was recorded during the night, subsequent to the RE session. The PSG was recorded using an EMBLA S7000® and recordings were taken in 30-second epochs.

Electroencephalographic recordings were performed according to the international system 10-20 (27). Four channels were used for the electroencephalograph (EEG), 2 channels for the electro-oculogram and 2 channels for the electromyogram (submentonian and legs). One ECG channel, a thermistor and nasal cannula, chest and abdominal bands, transcutaneous oximetrics and a sensor were used to establish the position of the trunk during sleep.

Interpretations of the PSG were performed according to standard criteria for sleep classification (28). Analyses included measures of SWS, REM sleep latency, TST, sleep efficiency, stages I, II, III and IV of NREM sleep and REM sleep, AHI, oxygen saturation and PLMs.

Except for periods of exercise and PSG monitoring, the volunteers were asked to go about their normal daytime activities. They were instructed to refrain from any extra exercise, evening tea or coffee, all alcohol, and naps. This information was assessed in the pre-PSG questionnaire.

### Statistical Analysis

Statistical analyses were carried out using the software Statistica 6.0 (StaSoft, INC®). Descriptive data from the samples are presented as means ± standard deviations and were analyzed by means of one-way ANOVA for repeated measures. The descriptions of the PSG parameters are presented as means ± standard deviations. For the comparative analysis of the PSG data, a paired t-test was used to compare the baseline and each of the three periods of experimental conditions. P-values were considered significant if less than or equal to 0.05.

## Results

We began with 47 volunteers; however, following the first PSG (prior to the RE session) 20 volunteers were excluded because 11 presented AHI > 15 and 9 presented with PLM > 5. The 27 volunteers remaining in the study were then arbitrarily divided into three experimental groups.

Table 1 presents the characteristics of the subjects with regards to age, body mass, height and body mass index (BMI). Data are presented for each of the three experimental groups (according to the period of the day during which RE was performed). No significant differences were found between the groups for these variables.

**Table 1 – Description of the characteristics of the sample distributed along the different periods**

| | n | Morning | n | Afternoon | n | Evening | p |
|---|---|---|---|---|---|---|---|
| Age (years) | 7 | 28 ± 8 | 10 | 27 ± 7 | 10 | 26 ± 5 | 0.86 |
| Body mass (Kg) | 7 | 75.7± 14.3 | 10 | 73.8 ± 10 | 10 | 72.1 ± 8.7 | 0.80 |
| Height (m) | 7 | 1.78 ± 0.11 | 10 | 1.76 ± 0.06 | 10 | 1.75 ± 0.07 | 0.74 |
| BMI (kg/m²) | 7 | 23.81 ± 2.34 | 10 | 23.8 ± 2.43 | 10 | 23.64 ± 1.96 | 0.98 |

**Data presented as mean ± standard deviation. BMI: Body Mass Index.**

**Table 2 – Description of the PSG parameters of the 2 nights (Basal and Exercise) to morning group**

| Morning | n | Basal | Exercise | p |
|---|---|---|---|---|
| SOL (min) | 7 | 7.73 ± 4.65 | 18.27 ± 27.04 | 0.36 |
| REM sleep latency (min) | 7 | 87.29 ± 45.57 | 73.14 ± 18.70 | 0.32 |
| TST (min) | 7 | 367.79 ± 44.50 | 363.21 ± 54.12 | 0.64 |
| Sleep efficiency (%) | 7 | 86.23 ± 7.69 | 86.26 ± 7.54 | 0.99 |
| Stage 1 (%) | 7 | 4.46 ± 2.61 | 4.74 ± 2.76 | 0.78 |
| Stage 2 (%) | 7 | 53.80 ± 4.38 | 55.24 ± 4.86 | 0.52 |
| Stage 3 (%) | 7 | 3.59 ± 1.65 | 4.64 ± 2.85 | 0.22 |
| Stage 4 (%) | 7 | 17.67 ± 4.52 | 16.96 ± 4.92 | 0.57 |
| SWS (Stage 3 + 4) (%) | 7 | 21.26 ± 4.66 | 21.60 ± 4.95 | 0.82 |
| REM sleep (%) | 7 | 20.50 ± 6.03 | 18.43 ± 3.54 | 0.36 |
| Wake (min) | 7 | 50.61 ± 29.9 | 37.87 ± 21.2 | 0.42 |

**Data presented as mean ± standard deviation. SOL: Sleep Onset Latency; TST: Total Sleep Time; SWS: Slow Wave Sleep.**

**Table 3 – Description of the PSG parameters of the 2 nights (Basal and Exercise) to afternoon group**

| Afternoon | n | Basal | Exercise | p |
|---|---|---|---|---|
| SOL (min) | 10 | 13.56 ± 19.86 | 4.27 ± 3.74 | 0.11 |
| REM sleep latency (min) | 10 | 78.40 ± 27.80 | 90.20 ± 36.30 | 0.52 |
| TST (min) | 10 | 386.65 ± 35.65 | 369.25 ± 25.07 | 0.22 |
| Sleep efficiency (%) | 10 | 90.90 ± 5.02 | 92.97 ± 2.0 | 0.14 |
| Stage 1 (%) | 10 | 2.75 ± 1.70 | 2.83 ± 1.10 | 0.87 |
| Stage 2 (%) | 10 | 54.89 ± 8.29 | 53.44 ± 7.48 | 0.53 |
| Stage 3 (%) | 10 | 3.67 ± 1.75 | 3.98 ± 1.74 | 0.64 |
| Stage 4 (%) | 10 | 17.19 ± 5.97 | 18.15 ± 4.70 | 0.63 |
| SWS (Stage 3 + 4) (%) | 10 | 20.86 ± 6.19 | 22.13 ± 5.18 | 0.45 |
| REM sleep (%) | 10 | 21.49 ± 6.49 | 21.62 ± 5.49 | 0.95 |
| Wake (min) | 10 | 25.17 ± 7.81 | 23.46 ± 6.41 | 0.48 |

**Data presented as mean ± standard deviation. SOL: Sleep Onset Latency; TST: Total Sleep Time; SWS: Slow Wave Sleep.**

**Table 4 – Description of the PSG parameters of the 2 nights (Basal and Exercise) to evening group**

| Evening | n | Basal | Exercise | p |
|---|---|---|---|---|
| SOL (min) | 10 | 6.59 ± 5.17 | 3.02 ± 4.15 | 0.06 |
| REM sleep latency (min) | 10 | 99.0 ± 39.12 | 86.41 ± 37.59 | 0.17 |
| TST (min) | 10 | 380.05 ± 35.75 | 383.26 ± 31.77 | 0.68 |
| Sleep efficiency (%) | 10 | 92.49 ± 3.27 | 94.21 ± 1.74 | 0.06 |
| Stage 1 (%) | 10 | 2.79 ± 1.61 | 2.46 ± 1.67 | 0.25 |
| Stage 2 (%) | 10 | 54.89 ± 4.42 | 55.02 ± 3.50 | 0.95 |
| Stage 3 (%) | 10 | 4.33 ± 1.69 | 4.17 ± 1.57 | 0.76 |
| Stage 4 (%) | 10 | 18.24 ± 5.15 | 18.04 ± 7.24 | 0.91 |
| SWS (Stage 3 + 4) (%) | 10 | 22.57 ± 5.30 | 22.21 ± 7.50 | 0.83 |
| REM sleep (%) | 10 | 19.74 ± 4.18 | 20.25 ± 6.14 | 0.78 |
| Wake (min) | 10 | 23.79 ± 8.92 | 20.33 ± 6.24 | 0.24 |

**Data presented as mean ± standard deviation. SOL: Sleep Onset Latency; TST: Total Sleep Time; SWS: Slow Wave Sleep.**

Tables 2, 3 and 4 present the results from the PSG measurements for two nights of sleep for each of the three groups (morning, afternoon and evening). A comparison of the sleep parameters collected after RE showed no significant alterations in sleep patterns among the various groups. However, the SOL and the sleep efficiency of the evening group showed a trend toward alteration (p = 0.06).

## Discussion

The current investigation does not demonstrate significant differences in the PSG parameters collected for groups that performed RE during different periods of the day (morning, afternoon, and evening). However, the SOL and the sleep efficiency of the evening group showed a trend toward alteration (p = 0.06).

In contrast to other studies in which significant alterations were detected in SWS (6, 8, 9, 14, 15) and in REM sleep (7, 8, 14, 18), this discrepancy may be attributed to differences in the types of exercise (AE versus RE), particularities of the characteristics of the subjects used in the investigations (athletic versus sedentary individuals) and differences in the volume and intensity of exercise performed in the studies.

In another study, sleep patterns were assessed following AE in trained individuals (16). The AE included one running session of moderate intensity (for 15 – 20 Km of distance) and one running session conducted until exhaustion (for 30 – 40 Km of distance). The timing of the exercise was kept constant throughout the investigation, between 12:00 and 19:00 h, with cessation 4 h prior to the volunteers' habitual bedtime. REM sleep latency was found to increase and REM sleep was reduced for the night on which exercise was performed to the point of exhaustion. No significant alterations in the duration of SWS were detected under any of the conditions, although significant increases in the density of EEG during SWS occurred for the night on which exercise was performed to the point of exhaustion. Alterations in EEG density during SWS were also observed in a study conducted by Hague et al. (8).

Few studies have examined the effects of RE on the sleep patterns of humans. These studies have been limited to examinations of the chronic effects of RE as it relates to the subjective perception of sleep by elderly subjects, without the use of polysomnography to objectively measure sleep parameters (29,30).

One study that did examine RE was Montgomery et al. (11), in which volunteers of the same age range as those observed in the present study were examined. Their investigation assessed the effects of afternoon resistance training on the sleep of power lifters. Despite the fact that these subjects were individuals who trained intensively for at least 2 hours a day, five times a week, and who had been on such a regime for over 12 months, no significant alterations were found in their sleep patterns on the days that training sessions were performed compared with those observed on rest day.

Taking into consideration the differences in physiological responses that arise from distinct forms of exercise (AE versus RE) and differences in subjects (trained individuals versus sedentary), the only significant alterations to sleep patterns have been found in studies concerning AE. Thus, the nature of exercise itself appears to exert a direct influence on sleep, eliciting distinct responses as well as corresponding physiological adaptations. One explanation for this phenomenon could be that the metabolic rate during RE is less than during AE (11), which would support both the hypotheses of energy conservation and of body restoration (31). Both of these theories postulate that alterations in sleep patterns could be due to the depletion of body energy and damage to tissue that occur when exercising, which recuperates with sleep.

To determine how the time at which exercise is performed affects sleep. Horne and Porter (32) carried out a study that compared the effects of AE performed in the morning (10:00 to 12:00 h) and in the afternoon (16:00 to 18:00h) on sleep patterns. They found significant alterations only in stage 3 of NREM sleep when AE was performed in the afternoon. Other studies were conducted at specific times of the day, e.g. 12:00 to 19:00h (16), the afternoon (11), or 90 min prior to habitual sleeping time (12), and only the study of Torsvall et al. (16) showed significant alterations to sleep. This finding supports the idea that significant alterations to the sleep may occur when exercise is performed 4-to-8 hours prior to habitual bedtime (17).

Buxton et al. (5) observed that high intensity AE performed in the early evening (17:30 to 19:30h) advances the melatonin phase. These researchers went on to argue that high intensity AE in the morning or afternoon has no influence on sleep because the circadian rhythm of melatonin remains unaffected. However, intense AE performed in the early evening would increase the propensity to sleep. as advances in the melatonin phase would occur (33). Also, the thermal load produced by exercise can be reflected in water loss and an increase in core temperature (19). Subsequent to this temperature increase there is a rapid decline in core body temperature, which increases the propensity to sleep (12) and seems to be especially potent in increasing SWS (19). All of these observations support the thermoregulatory theory.

Contrary to what has been found regarding AE, the RE protocol adopted in the current investigation did not produce any significant alterations in sleep patterns when performed during different periods of the day. Perhaps the intensity of exercise has to do with this since, moderate when it would be necessary a higher intensity of RE (for example 70% of the 1-RM or more) or a longer duration (volume of exercise), as concluded by one meta-analysis (17) that the minimal duration of exercise required to prompt any significant alteration in sleep would be 1 hr. Because the subjects in present study were sedentary individuals, we refrained from applying elevated loads in order to lessen the risk of injury. Thus, the duration of RE in the current study was 40-45 min in accordance with the recommendations of the American College of Sports Medicine (34). Determining these thresholds could open precedents for novel, long-term studies examining the chronic effects of RE on sleep. Also, we did not rule out the "floor and ceiling effect" when we scrutinized individuals with good quality sleep (35), which could have offset the threshold for sleep alteration.

The trend in the SOL ($p = 0.06$) in the evening RE group could represent a decrease in the anxiety levels of volunteers, which has been shown to occur when RE is performed with light and moderate loads (for example 50% of 1-RM) and can persist for 180 min (36,37). Along with the trend towards a decrease in the SOL in the RE group, we saw a trend toward an increase in sleep efficiency ($p = 0.06$).

Previous studies examining the effects of exercise on sedentary individuals have verified that there are indeed alterations in various physiologic parameters after some forms of physical exertion. However, based on the results obtained in the present study, we conclude that RE performed with a load equivalent to 50% of the 1-RM exerts no significant influence on the sleep patterns of sedentary adult individuals who have good sleep quality.

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