Gender differences in the relationship of sleep pattern and body composition in healthy adults

Diferenças do gênero na relação entre o padrão de sono e a composição corporal em adultos saudáveis

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ABSTRACT

Objective: To investigate the gender differences in relationship between body composition and sleep pattern in healthy subjects. Methods: Fifty-two healthy volunteers (27 women) participated in this study. Subjects underwent overnight polysomnography and measurements of body composition were taken in the following morning after a 12-hour fast. Validated protocols were used to evaluate sleep (polysomnography) and anthropometry (body mass, height, skinfolds and body circumferences). Results: A positive correlation between percentage of slow-wave sleep and percentage of lean body mass (r=0.46, p=0.016) was found in women. In men, awakenings during sleep were correlated positively with indices such as body mass index (r=0.62, p<0.01), fat mass (kg) (r=0.61, p<0.01), fat percentage (r=0.56, p<0.01), waist circumference (r=0.58, p<0.01), hip circumference (r=0.45, p<0.01), and waist-to-hip ratio (r=0.50, p<0.01). Body mass index, body fat percentage, waist circumference, and waist-to-hip ratio were correlated with apnea-hypopnea index (r=0.40, p=0.03; r=0.46, p<0.01; r=0.49, p<0.01; and r=0.56, p<0.01) in both genders. Conclusion: This study showed important statistical associations between different sleep variables and anthropometric characteristics in healthy subjects, suggesting a possible relationship between greater body fat deposition and impairment of sleep quality. In addition, it was noticed that these associations differ between genders and deserve further exploration.

Keywords: sleep/physiology; sleep disorders/diagnosis; body mass index; body fat distribution; polysomnography; human; female.

INTRODUCTION

Sleep has been increasingly recognized for its contribution to physical and psychological health¹. Moreover, sleep loss due to voluntary curtailment of time in bed has become a hallmark of modern society². Studies show that most people need between 7 and 8 hours of daily sleep, however, over less than 50 years, a reduction of sleep duration by 1.5 to 2 hours seems to have occurred²⁻⁴.

Study carried out at Centro de Estudos em Psicobiologia e Exercício (CEPE), São Paulo (SP), Brazil.
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Several studies have observed an association between short sleep duration and increased body mass index (BMI) or increased risk for being overweight. Compared with sleeping 7 to 8 hours per night, Patel et al. found that sleeping less than 5 hours was associated with a BMI that was, on average, more than 2.5 kg/m² in men and 1.8 kg/m² in women, after adjustments were made for multiple potentially confounding variables. Moreover, measures of adiposity also have been associated with time of sleep, showing that short sleep duration is associated with higher body fat percentage and waist circumference.

However few studies that examined the association between sleep quality and body composition in healthy individuals are available in the literature as well as gender differences in these variables. In front of this, the aim of this study was to investigate whether sleep architecture is associated with body composition in healthy adults and if this association is influenced by gender.

METHODS

Participants and study design
Fifty-two non-obese, healthy volunteers (27 women), between 19 and 45 years old (men: 27.3±6.0; women: 28.8±6.7), were recruited from the community and from the medical and technical staff and students of Universidade Federal de São Paulo (UNIFESP) and Associação Fundo de Incentivo à Pesquisa (AFIP). All individuals were sedentary (according to International Physical Activity Questionnaire – IPAQ), did not work in shift work, featured no abnormalities in a clinical electrocardiogram at rest and under physical strain, and did not have any health problems according to medical evaluation. After clinical evaluation, all subjects underwent overnight polysomnography (PSG). Subjects who presented values of apnea-hypopnea index (AHI) >15, and those who presented periodic leg movements (PLM) >5, assessed by means of PSG were excluded. Enrollment was voluntary after being informed about the procedures and objectives of the study.

The research was performed in Sleep Institute and Centro de Estudos em Psicobiologia e Exercício/Associação Fundo de Incentivo à Pesquisa (CEPE/AFIP) in 2007, situated in São Paulo city (SP), Brazil. It was approved by the Committee of Ethics of Universidade Federal de São Paulo (#0018/08) and the volunteers were informed about all the stages of the study and signed a written and informed consent before participation.

Sleep evaluation
Volunteers arrived at the sleep laboratory at 21h30 for electrode attachment and went to bed at 23h. Sleep parameters were recorded in one night of PSG in the laboratory. The PSG consisted of the simultaneous and continuous registration of the electroencephalogram (C4-A1, C3-A2, O2-A1, and O1-A2), left and right electrooculogram, submentonian and tibialis anterior muscles electromyography, electrocardiogram, nasal and oral airflow, thoracic cage and abdominal respiratory motion, oxyhemoglobin saturation (SaO2), snoring and body positioning. All data were collected and stored using an EMBLA S7000® and recordings were taken in 30-second epochs. PSGs were scored by a blinded, experienced sleep technician and staged according to standard criteria. Analyses included measures of total sleep time (TST), sleep efficiency, stages 1, 2, 3 (slow wave sleep – SWS), rapid eye movement (REM) sleep, REM sleep latency, wake time after sleep onset (WASO), AHI, oxygen saturation and PLM.

Arousals were defined according to guidelines of the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association, and respiratory events classified using criteria of the American Academy of Sleep Medicine. Episodes of apnea were defined as complete cessation of airflow for 10 seconds or more, and hypopnea was scored if there was at least a 50% reduction in airflow for 10 seconds or a discernable decrement in airflow for 10 seconds in association with either an oxyhemoglobin desaturation of at least 3% or an arousal. Apnea/hypopnea events were classified as obstructive, central or mixed according to the presence or the absence of breathing efforts and the AHI was calculated considering number of episodes of apnea and hypopnea per hour of sleep.

Body composition evaluation
Measurements of body mass, height, skinfolds, and body circumferences were taken in the following morning of the PSG exam after a 12-hour fast. Height was measured with a Sanny estadiometer (American Medical do Brasil Ltda., Brazil) with a 0.1 cm precision. Body weight was measured to the nearest 0.1 kg using a Filizola scale (Star model, Filizola, Brazil). Body mass (kg) divided by the square height (m²) was used to calculate BMI.

Three measurements of triceps, subscapular, midaxillary, chest, suprailiac, abdominal, and thigh skinfolds were taken using a Lange skinfold caliper (Beta Technology Incorporated, USA) with a 0.1 mm precision. The mean value was used to estimate the body fat percentage according to Jackson & Pollock and Jackson et al., equations for men and women, respectively.

A Sanny measuring tape (American Medical do Brasil Ltda., São Paulo) with a 10 mm precision was used to measure the waist (WC) and hip (HP) circumferences. WC divided by HP was used to calculate the waist-to-hip ratio.
The WC and WHR were considered central obesity indices. All measurements were taken by trained professional and all protocols were previously validated.

Statistical analyses

Student’s *t*-test for independent samples was used for gender comparisons between individuals’ characteristics of sleep and body composition. Pearson’s correlation was used to assess the association between sleep parameters and variables of body composition. Data were analyzed using Statistica 6.0 (StatSoft, Inc., Tulsa, OK, USA). All values were expressed as mean±standard deviation (SD). Statistical tests were accepted as significant when *p*≤0.05.

RESULTS

The characteristics of the volunteers are described in Table 1 and, in general, they were young adults, non-obese, with normal body fat percentage, and waist circumference. When compared by gender, men presented significantly higher values of body mass, height, BMI, lean mass, WC and WHR than women, as expected.

Regarding the sleep variables, women had reduced total sleep time (≤6 hours) in comparison with normative data. Men had a significantly higher percentage of stage 1 sleep and AHI than did women. AHI in men were higher when compared to normative data. Although there were no statistically significant differences between genders, the percent of waking after sleep onset was higher, and REM sleep was lower when compared to normative data.

The correlations of sleep pattern with BMI and body composition are described in Table 2. Stage 1 of sleep was positively correlated to lean mass and WHR (*r*=0.29). Stage 2 of sleep was also correlated to WHR (*r*=0.28 and *r*=0.36, respectively). WASO showed a significant correlation with weight and adiposity measures as BMI, fat mass, WC, and HC (*r*=0.35; *r*=0.42; *r*=0.40; *r*=0.29; *r*=0.31, respectively). Furthermore, AHI positively correlated with BMI, lean mass, fat mass, WC, and WHR (*r*=0.43; *r*=0.46; *r*=0.29; *r*=0.50; *r*=0.55).

When genders were separately analyzed, a positive significant correlation between SWS percentage and lean mass percentage was found in women (Figure 1), but not in men (*r*=0.08, *p*=0.33). Only women presented a negative correlation between fat mass percentage (*r*=-0.46, *p*=0.016) and SWS percentage.

<table>
<thead>
<tr>
<th>Table 1. Body composition and sleep characteristics of volunteers.</th>
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<td><strong>Body composition variables</strong></td>
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In bold p≤0.05; Student’s *t*-test.

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; TST: total sleep time; SWS: slow-wave sleep (stage 3 of sleep); REM: rapid eye movement; WASO: wake after sleep onset; AHI: apnea-hypoapnea index; PLM: periodic leg movements.

<table>
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<th>Table 2. Correlations between body composition measurements and sleep variables.</th>
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<tr>
<td><strong>TST (min)</strong></td>
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<td>Body fat (%)</td>
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<td>WHR</td>
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In bold characters: *p*≤0.05; Pearson’s correlation.

TST: total sleep time; Sleep effic: sleep efficiency; SWS: slow-wave sleep (stage 3 of sleep); REM: rapid eye movement; WASO: wake after sleep onset; AHI: apnea-hypoapnea index; BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio.
Only in men, WASO was positively correlated with BMI \( (r=0.62, \ p<0.01) \), fat mass \( (r=0.61, \ p<0.01) \), lean mass \( (r=0.41, \ p=0.04) \), fat percentage \( (r=0.56, \ p<0.01) \), WC \( (r=0.58, \ p<0.01) \), HC \( (r=0.45, \ p=0.02) \), and WHR \( (r=0.50, \ p=0.01) \), as shown in Figure 2. Furthermore, a positive correlation between WHR and AHI \( (r=0.51, \ p=0.01) \) was also found (Figure 3). All these correlations were not found in women.

**DISCUSSION**

In the present study, several significant correlations between anthropometric variables and sleep were found, indicating that these aspects can be associated. It is important to highlight that a bidirectional influence can occur between sleep and anthropometric variables, that is, sleep may influence body composition and body composition can influence sleep pattern. The first is well demonstrated in the literature, but little is known about how parameters like body fat percentage, waist and hip circumferences can affect sleep pattern.

Although our results indicated expected differences in anthropometric variables between the genders, the same occurred with sleep pattern which evidenced a higher stage 1 and AHI in men, a finding previously reported by our group. Previously, Silva et al.\(^\text{18}\), demonstrated in a large group of Brazilian patients that men had higher stage 1, stage 2, and AHI than women, whereas women had significantly more SWS than men.

Given the speculative nature of these results and the lack of evidence in this area, it is difficult to compare these results with other researches. One of the few studies that analyzed the relationship between body composition and sleep was done by Rontoyanni et al.\(^\text{16}\). Their results demonstrated a negative correlation between sleep duration and fat percentage in healthy women, supporting the idea that sleep duration is significantly associated with body fat. On the other hand, in a study conducted by Stranges et al.\(^\text{15}\), negative correlations between sleep duration and body mass and central adiposity were observed. In our study no association between sleep duration and greater body mass and/or adiposity was found. Nevertheless, we verified an association between body composition and sleep quality variables.

Rao et al.\(^\text{17}\) published the first large scale study to examine the relationship of sleep architecture, specifically SWS, with measures of body composition such as BMI, waist circumference and percentage body fat. This study showed that older men in the lowest quartile of SWS had an average BMI of 27.4\(\text{kg/m}^2\), compared to 26.8 for those in the highest quartile of SWS. Furthermore, participants in the lowest quartile of SWS had a 1.4-fold increased odds for obesity \( (p=0.03, \ 95\% \text{CI}: 1.0-1.8) \) compared to those in the highest quartile. Authors concluded that independent of sleep duration, percentage time in SWS is inversely associated with BMI and other measures of body composition. The authors
did not found a relationship between adiposity variables and SWS. In our study we observed in women a negative correlation between percentage of SWS sleep and percentage of fat mass. It also was observed that the WHR correlates negatively with the percentage of stage 4 sleep and positively with stage 1 sleep in both genders. According to Rao et al., it is possible that increased BMI may alter sleep architecture and decrease SWS.

The alteration of the ideal sleep architecture can bring about harmful effects. As an example, Tasali et al. in a recent study demonstrated that the reduction of the SWS was related to a greater insulin resistance, indicating its role in glucose homeostasis. These data suggest that a smaller amount of SWS (which occurs in obese individuals) can contribute to an increased risk of type 2 diabetes.

Although in our study it was not possible to demonstrate a cause-effect relationship between body composition and apnea, some positive correlations between AHI and anthropometric variables were found especially in men, demonstrating that body fat distribution can be associated with a higher risk for apnea. Some studies show that obesity is a pathogenic factor in apnea and that approximately 70% of the patients with sleep apnea are obese. This association occurs because excessive weight can lead to a pharyngeal narrowing due to the fat deposition on the pharynx walls or on parapharyngeal structures, such as tongue, soft palate and uvula. Still, the risk of apnea development is more associated with the accumulation of fat in the central region, a fact also observed in the present study.

The role of sleep fragmentation in the relationship between sleep duration and obesity it is not clear yet. In the Rotterdam Study, whereas actigraphy was used to assess sleep, the degree of sleep fragmentation was a stronger predictor of adiposity than reduced sleep duration. Persons with more fragmented sleep had a higher BMI and more obesity, and the association of short sleep with obesity was substantially attenuated after adjustment for sleep fragmentation. This indicates that sleep fragmentation may be part of the mechanism by which short sleep is related to a higher prevalence of obesity. The results of this study are in agreement with the data described by van den Berg et al. However, Rao et al., did not find significant relationship between arousal index (as a measure of sleep fragmentation) and measures of body composition.

Some significant associations between anthropometric variables and sleep differed between genders (SWS and lean and fat mass in women, and WASO and BMI, fat mass, lean mass, fat percentage, WC, HC, and WHR in men). The potential gender difference in the relationship between sleep and adiposity deserves further exploration, especially since discordant have also been observed in different age groups. Future metabolic studies should be done in different genders to determine if they have a different hormonal response to short sleep duration.

A limitation of the present study was the single night of PSG. An adaptation to the laboratory could potentially influence the response to sleep. Another limitation is that we did not control menstrual cycle phase of women involved in the study.

This study demonstrated an important association between different sleep variables and adiposity measurements in healthy individuals, suggesting that a greater deposition of body fat can be associated with an impairment of sleep quality and not only the inverse, as shown in several studies. However, more studies are necessary to elucidate the real influence of sleep and its disturbances on several factors responsible for the control of body mass.

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