REVISTA NEUROCIÊNCIAS

Original

Objective effects of white noise on the sleep of university students: a pilot study

Efeitos objetivos do ruído branco no sono de estudantes universitários: um estudo piloto

Efectos objetivos del ruido blanco en el sueño de estudiantes universitarios: un estudio piloto

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Resumo

Objetivo. Avaliar as variações do padrão de sono por meio de polissonografia após exposição ao ruído branco. **Método.** A polissonografia de noite dividida foi realizada em nove estudantes universitários, com idade média de 20,7 ± 1,6 anos. Dormindo em um ambiente controlado e tranquilo, eles não foram expostos ao ruído branco durante as primeiras 4 horas da noite, sendo expostos ao ruído branco nas 4 horas restantes. **Resultados.** O ruído branco não afetou a eficácia do sono. O número de despertares não aumentou com a exposição ao ruído branco. Houve um aumento significativo no estágio inicial do sono (N1), não esperado na segunda metade da noite. O sono REM, esperado para acontecer principalmente durante a segunda metade da noite, foi ligeiramente menor do que o normal. **Conclusão.** Neste estudo piloto, a exposição ao ruído branco não afetou a eficácia do sono, nem interrompeu o sono por despertares. Não foi possível mostrar nenhum outro benefício dos parâmetros de qualidade do sono.

Unitermos. Polissonografia; Distúrbios do Sono por Sonolência Excessiva; Atenção; Hipersonia; Ruído; Universidades

Abstract

Objective. To assess sleep pattern variations through polysomnography after white noise exposure. **Method.** Split-night polysomnography was performed on nine university students, mean age of 20.7±1.6 years. Sleeping in a quiet controlled environment, they were not exposed to white noise during the first 4 hours of the night, being exposed to white noise the remaining 4 hours. **Results.** White noise did not affect sleep efficacy. The number of arousals did not increase with the exposure to white noise. There was a significant increase in the initial stage of sleep (N1), not expected in the second half of the night. REM sleep, expected to happen mostly during the second half of the night, was slightly lower than normal. **Conclusion.** In this pilot study, white noise exposure did not affect sleep efficacy, nor did it

disrupt sleep by arousals. It was not possible to show any other benefit of sleep quality parameters.
Keywords. Polysomnography; Disorders of Excessive Somnolence; Attention; Hypersomnia; Noises; Universities

Resumen

Objetivo. Evaluar las variaciones del patrón de sueño mediante polisomnografía tras la exposición a ruido blanco. **Método.** Se realizó polisomnografía de noche dividida a nueve estudiantes universitarios, con una media de edad de 20,7 ± 1,6 años. Durmiendo en un ambiente tranquilo y controlado, no estuvieron expuestos a ruido blanco durante las primeras 4 horas de la noche, estando expuestos a ruido blanco las 4 horas restantes. **Resultados.** El ruido blanco no afectó a la eficacia del sueño. El número de despertares no aumentó con la exposición al ruido blanco. Hubo un aumento significativo en la etapa inicial del sueño (N1), no esperado en la segunda mitad de la noche. El sueño REM, esperado que ocurra principalmente durante la segunda mitad de la noche, fue ligeramente inferior a lo normal. **Conclusión.** En este estudio piloto, la exposición al ruido blanco no afectó a la eficacia del sueño, ni interrumpió el sueño por despertares. No fue posible demostrar ningún otro beneficio de los parámetros de calidad del sueño.
Palabras clave. Polisomnografía; Trastornos de Somnolencia Excesiva; Atención; Hipersomnia; Ruido; Universidades

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INTRODUCTION

Sleep is essential to maintain the quality of human life. It is the period responsible for regenerating the brain functions and immune system activities, and giving the sensation that the energy spent during the day is restored[1]. A healthy night of sleep in a quiet environment can ensure effective organism functioning and therefore, improved performance of the activities of daily living[2]. The maximum noise level inside the home during the night should not exceed 35 dB(A) with windows open or 30 dB(A) with windows closed[3]. The World Health Organization (WHO) indicates that indoor noise levels should be kept below 40 to 50 dB(A) to ensure undisturbed sleep[4].

Some drug strategies and cognitive-behavioral therapy are used to induce sleep and improve its quality[5]. Initial studies point to listening to pure/colored noise (e.g., white and pink noise), natural sounds (e.g., rain, waterfall, and whispers), and classical music or other genres of the person's preference as an alternative method[6]. White noise, also called Gaussian or thermal noise, is a broadband noise with approximately equal acoustic energy at all audible frequencies. It was named white noise because it is analogous to white light – i.e., white noise, like white light, has the same amount of energy in each wave, regardless of the frequency value[7].

Auditory stimulation leads to relaxation, distraction, synchronicity between biological rhythms and the beat of the auditory stimuli, sound masking, and the pleasure of listening to favorite music[8]. Studies have described the potential effect of white noise on weight gain in preterm babies in Neonatal Intensive Care Units[9], decreased reading time and increased writing fluency in young people with attention-deficit/hyperactivity disorder[10], and decreased agitated behavior in older adults with dementia[11].

A study in intensive care unit patients observed the impact of auditory stimulation effect on sleep. The quality of sleep of adult patients improved by using different types of noise twice a day for 3 consecutive days – white noise was used on day 1; pink noise, on day 2; and brown noise (natural sounds, like rain), on day 3[12].

Intervention with white noise during the night also improved the quality of sleep in a population daily exposed to intense noise pollution and with previous sleep complaints, according to subjective and objective actigraphy parameters[13].

A systematic review specifically analyzed the positive effects of different noises, and the authors found that 19 out of the 34 studies included in the review reported sleep improvements. Also, six (33%) of 18 studies that used white noise observed improvements; nine (81.9%) of 11 studies that used pink noise found positive effects; and four (66.7%) of six studies that used multiaudio (i.e., combinations of white and pink noise, music, and silence) obtained improvements in sleep parameters[14].

However, it is not yet possible to state which stimuli best improves sleep, as various stimuli and different unstandardized parameters were used for the measurements, such as a sleep diary instead of polysomnography[6].

Polysomnography is considered the gold standard to objectively measure sleep, as it monitorizes various parameters, including cardiac, brain, muscle, and respiratory signals. It allows us to determine the sleep architecture and possible changes throughout the night[15].

Despite indicating the beneficial effects of noise on sleep, the studies available so far show nonuniform sleep quality results, and only a few of them assessed sleep parameters by polysomnography[16], thus justifying further studies to better understand the topic. It was hypothesized that white noise exposure during sleep favors sleep onset, maintenance, and quality. Hence, this study aimed to assess changes in sleep parameters observed with polysomnography before and during white noise exposure.

METHOD

Ethical aspects

This study was approved by the Human Research Ethics Committee under number 2.299.916 (CAAE: 72327417.0.0000.8101). Participation in the research was voluntary and free, and subjects were assessed only after signing an informed consent form.

Sample

This interventional study comprised nine volunteer university students, seven males and two females, aged 18 to 24 years. Subjects with body mass index above 25kg/m², Mallampati above 1, respiratory complaints (nasal breathing, snoring), sleep complaints, respiratory events such as apnea and/or hypopnea detected with polysomnography, and comorbidities were excluded.

Procedures

Subjects were submitted to medical history survey and clinical assessment to verify complaints of snoring, breathing pauses, daytime sleepiness, sleep onset and maintenance, height, weight, arterial pressure, Mallampati scale classification, and medication use. These data were used to identify exclusion criteria; hence, they were not presented in the results.

All volunteers performed an overnight polysomnography in the split-night mode at an equipped and accredited sleep laboratory, sleeping in a quiet and controlled environment. The first part of the polysomnography was recorded from 10p.m. to 2a.m. without white noise exposure. The second assessment took place from 2 to 6a.m. with continuous white noise, played from the Relax Melodies application, transmitted to a loudspeaker via Bluetooth at 40 dB(A), monitored with a sound level meter (Brand 01dB, model SOLO), within intensity limits proposed by WHO.

Polysomnography was analyzed by a sleep medicine specialist, according to the classification of the American Academy of Sleep Medicine[15]. The criteria used to define hypopnea were a 50% decrease in respiratory volume associated with 3% oxygen desaturation for at least 10 seconds.

The following parameters in the sleep cycle were assessed sleep efficiency, non-rapid eye movement (NREM) stages, encompassing N1 (superficial sleep), N2 (intermediate sleep), and N3 (deep sleep), and rapid eye movement (REM) stage. These variables were assessed in minutes and percentages. The number of arousals, periodic leg movements, heart rate variation, and oxygen saturation were also assessed.

Statistical analysis

IBM SPSS Statistics Standard Edition, version 21.0, was used to analyze data and determine correlations. Collected data were tabulated and submitted to descriptive analysis, using mean values. The Shapiro-Wilk test analyzed the normality of the data. The paired t-test assessed whether there was a significant mean difference between the moments with and without noise. The level of statistical significance was set at $p<0.05$.

RESULTS

The sample comprised nine volunteers with a mean age of 20.7±1.6 years, who were submitted to polysomnography for 8 hours.

The exposure to white noise did not affect sleep efficiency. However, we observed a significant increase in N1 (superficial sleep) after noise exposure. Also, the time awake showed a tendency to increase, although not reaching significancy.

The other sleep stages seemed not to be affected by the white noise exposure, intermediate sleep N2 showing a similar duration. Deep sleep N3 and REM sleep are more pronounced in the first and second half of the night respectively, according to their normal physiological distribution, as exposed in Table 1.

The number of EEG arousals, leg movements, or sympathetic activation expressed by heart rate variation did not change with the exposure to noise, as seen in Table 2.

Table 1. Polysomnographic measures regarding wake time, sleep stages, and sleep efficiency.

Parameter (Mean value)	Without noise	With noise	p
Wake time (%)	18.22	23.28	0.153
N1 sleep (%) (NL = 2-5%)	3.31	6.06	**0.049***
N2 sleep (%) (NL = 45-55%)	59.80	59.21	0.85
N3 sleep (%) (NL = 15-20%)	26.54	15.90	**0.016***
REM sleep (%) (NL = 20-25%)	10.34	19.59	**0.006***
Sleep efficiency (%) (NL = > 85%)	90.98	88.31	0.168

NL: normal values; N1: superficial sleep; N2: intermediate sleep; N3: deep sleep (NREM: non-rapid eye movement); REM: rapid eye movement. Statistical test: paired t-test, considering $p<0.05$.

Table 2. Comparison of arousals, O2 desaturation, leg movements, and heart rate with and without noise exposition.

Parameter (mean values)	Without noise	With noise	p
Arousals	56.11	52.11	0.701
SpO2	94.56	94.78	0.446
Leg movements	12.89	14.00	0.388
Heart rate	55.67	54.56	0.238

SpO2: oxygen saturation. Statistical test: paired t-test, considering $p < 0.05$.

DISCUSSION

This study aimed to assess the effect of white noise on the macro and microarchitecture of sleep in normal healthy subjects, as well as physiological variables that may accompany and/or be affected by changes in the quality of sleep. The study population comprised of young adult volunteers without previous sleep disorders, comorbidities, or medication use with possible interference on architecture and quality of sleep.

The exposure to white noise led to an increase in superficial sleep, even above the normal physiological limit.

Although not significant, there was also an increase in the time awake. These results do not make it possible to conclude in favor of the hypothesis that white noise exposure improves sleep onset, unlike those reported by other studies, enrolling participants with previous complaints of sleep disorders[13]. Similar to our results, Saeda et al also observed longer wake time in 11 adults with sleep complaints, when they were exposed to white noise than when exposed to pleasant noise (ocean sounds)[17].

The increase in N1 might be explained by at least initial discomfort and the need to adapt to the new environment with white noise exposure. In this sleep stage, external stimuli as noise can still be heard, as they are only blocked in N2[18,19].

In both night periods addressed in the study (with and without white noise exposure), the intermediate stage of sleep (N2) remained above normal values. Noise, even at weak intensities, can cause a temporary passage from deeper to lighter sleep[19]. Increase of N2 is observed in older populations above 60 years old[20]. External factors (e.g., pain, pathologies, noise pollution, and poor sleep hygiene habits) also will influence the sleep architecture[21]. Considering these principles, our sample comprised young adults without any comorbidities or factors related to changes in sleep quality. Noise exposure was the only causal factor that was introduced.

This analysis was reinforced by the time awake. Even though it did not have statistical significance, it increased in five minutes after noise exposure. Decreased sleep efficiency and wake time were associated with exposure to the noise of aircraft engines in neighbors of a large airport[22].

The sleep architecture, as the number of arousals and the percentage of deep sleep N3 and REM sleep, seemed not to be affected by the exposure of noise. It is important to point out that the first half of the night is expected to have a greater proportion of N3 sleep, whereas during the second half occur more and longer REM sleep cycles[23]. The split-night analysis cannot associate any variation of these sleep stages due to noise exposure.

Sleep is the period of recovery of physiological functions such as heart and breathing rate, arterial pressure, and so forth, with decreased activity of the sympathetic autonomous system and increased parasympathetic (vagal) tone in response to the cardiovascular control mechanism during sleep[2]. On the other hand, the heart rate changes in response to various stimuli, such as stressful conditions or noise exposure, especially at high levels and when deemed uncomfortable[24,25]. The present research did not identify heart rate differences between the two monitored periods, with and without white noise exposure. These findings agree with a study that investigated the effect of noise on sleep and autonomic activity in children[26], as well as a study that conducted a similar investigation in young adults[27].

Periodic leg movements can be caused by physiological changes related to the nervous system, triggering spastic leg movements[28]. The present study did not find significant differences in leg movements with and without white noise exposure. Literature lacks similar studies to compare this finding.

Our study has several limitations such as the small sample size and the split-night polysomnography. The full night in-lab polysomnography is an expensive examination with limited access in the Brazilian Unified Health System. To minimize the consequences of these limitations, only volunteers with very specific characteristics were invited, with rigid exclusion criteria regarding factors that might influence the structure of sleep (e.g., alcohol consumption, smoking, medication use, previous sleep deprivation, risk of respiratory sleep disorders, and/or complaints compatible with initial, maintenance, or final insomnia.

The strengths of this paper doubtlessly reside in the homogeneous characteristics of the group of volunteers, whose age range was narrow and whose weight and life habits were similar. The analyzed data were extracted from an objective examination by polysomnography, which is considered the gold standard to assess sleep characteristics and sleep architecture.

Lastly, this study should be continued by investigating the effect of noise on normal sleep, with a larger sample, consolidating the strength of evidence of impacting results obtained in this first trial, considering that published scientific studies address populations with previous sleep disorders.

CONCLUSION

In this pilot study, white noise exposure during sleep did not improve sleep onset. On the other side, exposure to white noise did not affect sleep efficacy, nor disrupt sleep by arousals. It was not possible to show any other benefit of sleep quality parameters, or sleep maintenance.

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