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Effects of negative oxygen ions on sleep quality

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Abstract

This paper aims to investigate the effects of negative oxygen ions on sleep quality. An experiment was held using both subjective and physiological methods on 33 subjects (16 females and 17 males). The subjective assessment on sleep quality was surveyed and the duration of every sleep stage was determined. The results of this experiment indicate that the negative oxygen ions have a significant effect on sleep quality. The subjective results indicate that with negative oxygen ions subjects fell asleep easier, meanwhile, the objective results indicate that the duration of sleep onset latency was shortened and the slow-wave sleep was lengthened. All these results show that negative oxygen ions can improve people's sleep quality.

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Keywords: *Negative oxygen ions; Sleep quality; Electroencephalogram (EEG); Subjective questionnaire*

1. Introduction

A normal person spent 1/3 of his life sleeping. Good sleep has beneficial effects on health, both physically and psychologically, and helps improve productivity during daytime. There are many factors in sleep quality such as health states, emotional states, thermal environment and bedding conditions [1]. In the summer people feel sleepier at higher temperature [2] and in the winter people fall asleep more easily at higher temperature [3].

Negative oxygen ion has been known as a "natural convalescent factor" since it was discovered. It has been suggested that negative ions exert beneficial effects on physical state, psychological state and performance [4]. Negative oxygen ions were verified to be capable of improving human being's feeling of comfort and relieving their

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fatigue [5]. Previous findings have also demonstrated that negative oxygen ions can evidently improve sleep quality of insomniacs with exact effect [6].

However, few studies focused on its impact on healthy subjects. And negative oxygen ion is usually generated by high voltage that will produce ozone, which may cause another indoor pollution. In this study, we shall produce negative oxygen ion by a new natural and healthy way using vermiculite calcium silicate board without producing ozone and conduct experimental researches on 33 healthy subjects to explore how negative oxygen ions influence their sleep quality, both physiological measurements method and subjective questionnaires method will be adopted.

2. Methods

2.1. Subjects

33 college students were recruited for this experiment. Each subject was informed of the experiment procedure in advance but blinded from the experiment variables and provided a written informed consent.

The candidates should be healthy without any medical history of cardiovascular disease and have no drinking or smoking habits. A Pittsburgh Sleep Quality Index (PSQI) global score should be ≤7 to avoid sleep disturbance among subjects [7]. The Anthropometric data is shown in table 1.

Table 1. Anthropometric data of the subjects

Gender	Number	Age	Height (cm)	Weight (kg)	BMI (kg/cm2)	PSQI
Male	17	23±2	175.5±4.3	65.3±6.8	21.2±1.7	2.5±1.5
Female	16	23±2	161.4±4.9	53.4±6.4	20.5±1.6	3.8±2.3
ALL	34	23±2	168.7±8.5	59.6±8.8	20.8±1.7	3.2±2.0

Note: ***BMI*** Body mass index, ***PSQI*** Pittsburgh sleep quality index.

2.2. Experimental design

Two conditions with different exposure levels to negative oxygen ions were compared. The concentrations were about 400 unit per cubic centimeter (c1) which is a normal condition in normal environment and 4000 unit per cubic centimeter (c2), which is higher than normal, with a specific board releasing negative oxygen ions respectively. Each subject attended the experiment twice, the former was under c1first, then c2 after 3 weeks. With the interval of 21 days the sequence effect and the first night effect can be ignored.

The experiments were performed in a 15 m2 chamber in winter in an ambient temperature of 21℃±1℃, a relative humidity of 50% ± 10% and an air velocity of ≤0.2m/s that were kept constant throughout the experiments. The concentration of negative oxygen ions was tested before and after sleep and maintained at the designed level.

2.3. Measurements

Brief Profile of Mood States was adopted to evaluate the subjects background mood state and their mood state in the environmental chamber. Indoor air quality was surveyed to evaluate subjects feeling to environmental chamber. Sleep quality assessment was carried out the next morning to evaluate subjective sleeping satisfaction of the last night.

The EEG and ECG were continuously measured throughout the whole sleep period via polysomnographic sleep recording (Somté 32 PSG, Compumedics, Australian).

2.4. Experimental procedure

Each experiment session lasted for 650 min from 9:00 p.m. to 7:50 a.m. In winter of China, temperature steps have impact on human discomforts [8,9], so after entering the preparatory chamber at 9:00 P.M the subjects had a 10 minutes rest, then they filled out the mood states questionnaire. Then the subject entered the environmental chamber at 9:20 P.M and waited for 30 minutes to adapt to the indoor environment. From the moment the subjects entered the chamber, they wore long-sleeved cotton T-shirts and long cotton pants, the estimated clothing value is 0.94 clo [10]. After adaption, the indoor air quality and mood states evaluation were performed. Next, the experiment operator helped the subject to wear the instrument and to set physiological parameter probe; this process lasted 90 minutes. At 11:30 P.M, lights were turned off and sleeping time started. Physiological parameters were measured and recorded continuously throughout the sleeping period until subjects woke up the next morning at 7:30 A.M. After the probe was removed, the subject filled out questionnaires regarding sleep quality. The detailed schedule of each condition is shown in Figure 1.

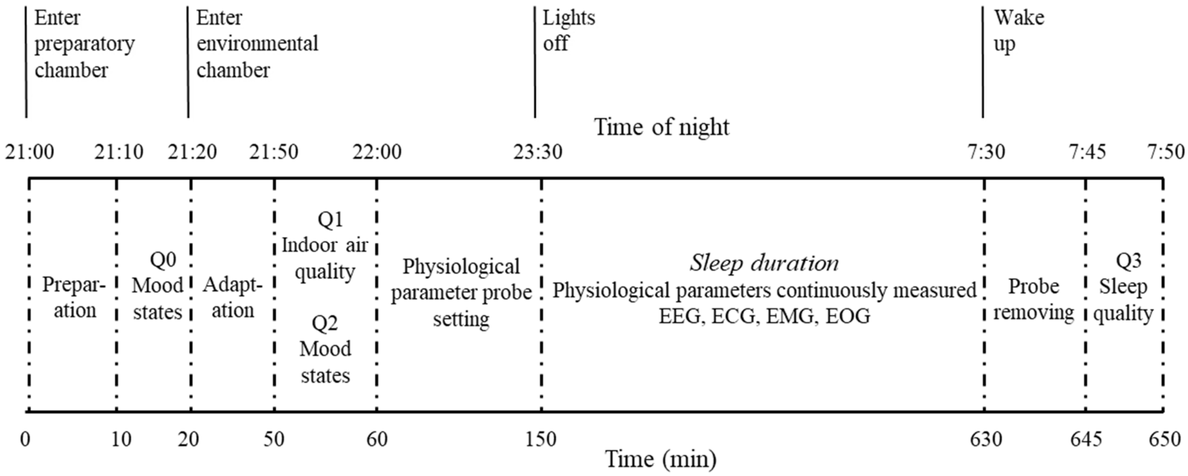

Fig. 1. Detailed procedure of the sleeping experiment.

2.5. EEG analysis

The whole sleep period is divided into two main types: Non-Rapid Eye Movement (NREM) sleep and Rapid Eye Movement (REM) sleep. NREM is further divided into three types: N1, N2 and N3 which is also called slow-wave sleep period. The duration of each period was obtained based on EEGs. The EEGs are divided to four simple periodic rhythms characterized by different frequencies, as follows: delta (δ), theta (θ), alpha (α), and beta (β) [11]. Each sleep stage has its own distinctive neurologic feature with different a combination of four EEGS. The sleep onset latency (SOL), namely, the length of time needed from full wakefulness to sleep, and slow-wave sleep (SWS), were two important indices adopted to evaluate the sleep quality.

2.6. Statistical analysis

Kolmogorov–Smirnov test was first performed for normality. The Paired Samples T test was used on normally distributed data while Wilcoxon Signed-Ranks test was used on not-normally distributed data. $P<0.05$ is considered significant.

3. Results

3.1. Result of the subjective assessment

In the mood states assessment the subject was shown 30 adjectives which described different mood states, each mood state has 5 levels from 0 to 4, a higher score indicates a stronger mood [12]. These mood states are reduced to 6 affective factors: Tension-Anxiety (T), Depression-Dejection (D), Anger-Hostility (A), Vigor-Activity (V), Fatigue-Inertia (F) and Confusion-Bewilderment (C).

The result of T-score and V-score in background survey (Q0) are shown in figure 2, other affective factors don't have significant differences. Average T-score significantly decreased from c1 (1.52) to c2 (0.7), namely, subjects were more tensional and anxious at c1 because they were unclear about the following experiment; meanwhile, average V-score significantly decreased from c1 (8) to c2 (5.82), namely, subjects were less vigorous and active at c2 which is probably because that they were in exam period so they worked harder during the day. However, both these significant differences disappeared in Q2 after 30 minutes adaptation in experimental chamber.

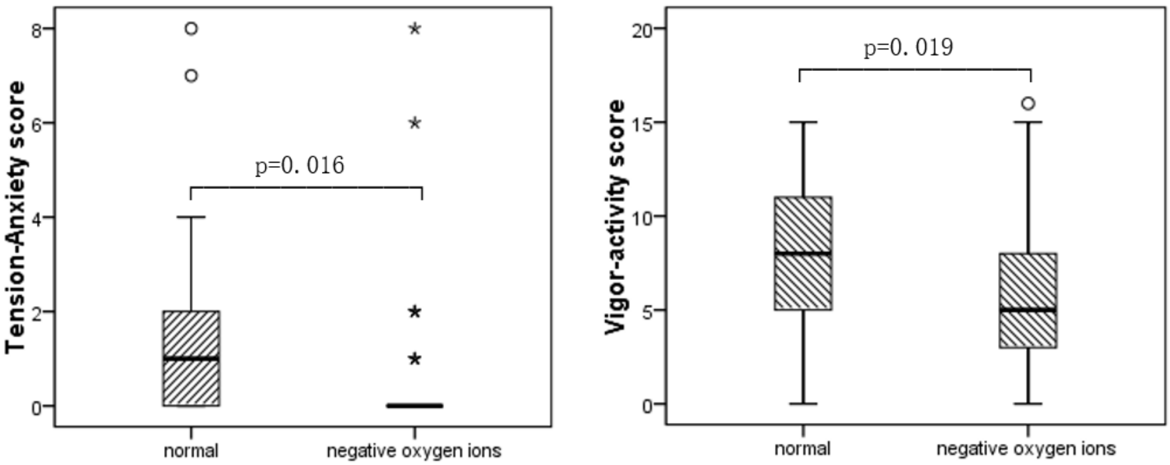

Fig. 2. Mood states assessment at different concentrations of negative oxygen ions.

The sleep quality assessment contained five items: calmness of sleep, ease of falling asleep, ease of awakening, freshness after awakening and overall satisfaction of sleep. All items consisted of five-graded response alternatives [13].

The results of the subjective evaluation of the ease of falling asleep are shown in Figure 3. A significant difference (p=0.019) was observed. The percentage of “very difficult” were 0% at both c1 and c2, “very easy” and “fairly easy” both increased at c2, whereas “neither easy nor difficult” and “quite difficult” decreased, namely, the subjects fell asleep more easily at c2.

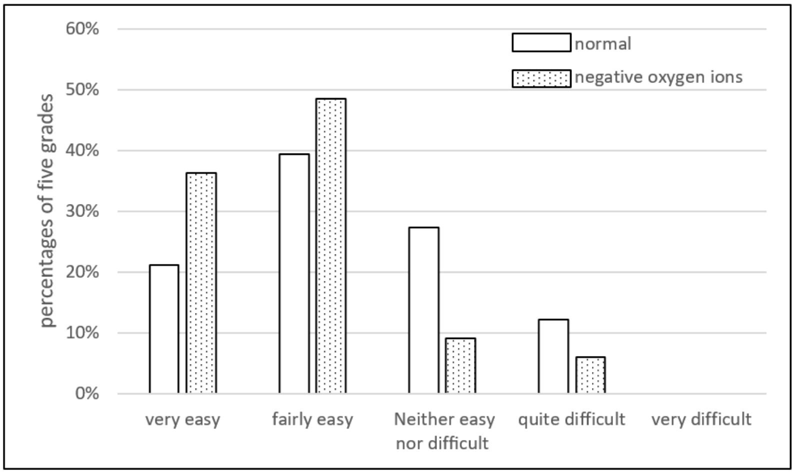

Fig. 3. Percentage of ease of falling asleep evaluation diagram.

3.2. Result of the physiological measurements

The duration of SOL is shown in fig 4. Significant difference in SOL between the two conditions (p<0.05) was determined. Average SOL decreased from c1 (11 minute) to c2 (8 minute), which is consistent with the result of the subjective evaluation.

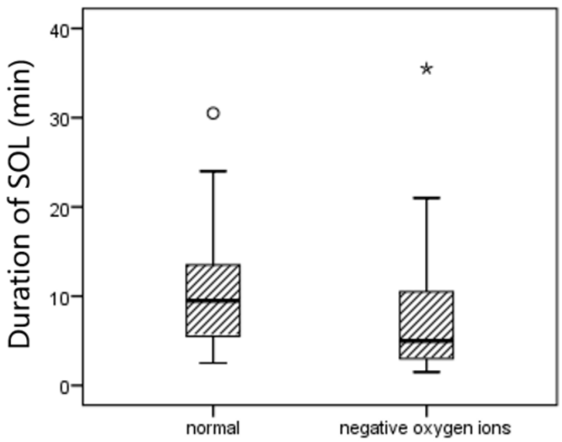

Fig. 4. Duration of SOL at different concentrations of negative oxygen ions.

The time percentages of four sleep stages (REM, N1, N2 and SWS) for the entire night are shown in fig 5. The durations of SWS significantly increased from c1 to c2 while REM slightly increased from c1 to c2, N1 and N2 slightly decreased from c1 to c2.

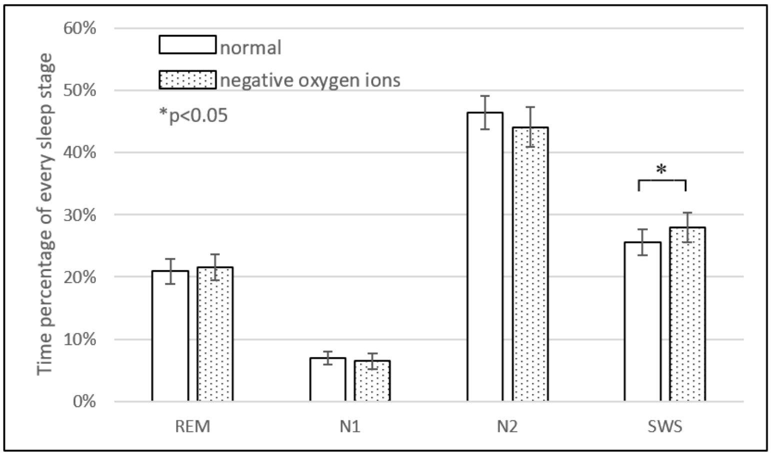

Fig. 5. Time percentages of every sleep stage for the entire night at different concentrations of negative oxygen ions (error bars represent the SD).

Among all indices, SOL and SWS directly reflect the sleep quality. A shorter SOL and longer SWS indicates a higher sleep quality. Therefore, under negative oxygen ions condition, the duration of falling asleep was shorter, whereas the duration of deep sleep was longer.

4. Discussion

The questionnaire results show that when they slept in the room with negative oxygen ions, the subjects fell asleep faster, which meant that the sleep latency was shortened. The SOL and SWS measurements verify that negative oxygen ions are beneficial to the subjects be-cause falling asleep was easier and deep sleep was longer. Based on both subjective and objective results which are in accordance, negative oxygen ions significantly improve the sleep quality. Thus, sleep quality can be improved by increasing the concentration of negative oxygen ions. Further research needs to be done on the mechanism of these findings.

5. Conclusion

The effects of the negative oxygen ions on sleep quality were investigated using subjective assessments and objective methods (EEGs). The following conclusions were reached:

1. The subjective assessment shows that the subjects fell asleep more easily in the room with negative oxygen ions, which is also demonstrated by objective assessment index, SOL measurement.
2. SWS, the index which suggests deep sleep thus reflects sleep quality, was longer under negative oxygen ions.
3. Negative oxygen ion is not only a treatment for patients of insomnia but also improves sleep quality of normal healthy people.

Acknowledgements

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