ORIGINAL ARTICLE

SLEEP DEPRIVATION AND EXTRAOCULAR MUSCLES: A CROSS SECTIONAL STUDY

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Background: Sleep is a state of altered consciousness where the sensory activity continues but voluntary muscle movement and interactions with surroundings are greatly reduced. People tend to have inadequate amount of sleep and as a result develop a sleep debt which adversely affects their functions, including the extra ocular muscles. This study was planned with the objective to compare the extraocular potentials of sleep deprived study subjects with those that had slept well. **Methods:** This was a cross-sectional study. BioPac data acquisition unit was used to record electro ocular potentials of sleep deprived and well slept students during pendular tracking, vertical tracking, simulated tracking and saccadic eye movements. **Results:** Of the 17 medical students, there were 8 males and 9 females. The mean sleep debt for experimental group was 27.3±3.15 hours and the mean sleep time for the control group was 8.2±1.5 hours. There was a slight decrease in the overall mean voltage of the experimental group during the pendulum tracking and simulated pendulum tracking movements. A decrease in the mean voltage for vertical tracking and simulated vertical tracking was also observed between the two groups. There was a delay in the saccadic movements noted in experimental group as compared to control. **Conclusion:** Sleep debt affects the electro ocular potentials causing a decrease in the voltage of extraocular potentials recorded in tracking movements and a delay in time taken for saccadic movements.

Keywords: EOG, sleep deprivation, extraocular muscles, electro ocular potential

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INTRODUCTION

Electrooculography is a technique for measuring the electrical potentials generated during movements of the eyeball between the electrodes placed on the face. The electrooculography tracings that are recorded, when the eyes are moving between two fixation points, inducing a deflection of fairly constant amplitude is called an electrooculogram.[1]

Electrooculography (EOG) was introduced for diagnostic purposes in neurology and otology[2] and is still being used for ophthalmological diagnosis of diseases and conditions which affect the ocular apparatus such as sleep debt. It has many modern day applications, such as Human-Machine Interface (HMI) application, for the patients suffering from paralysis.[3] The potential difference generated around eyes due to the movement of the eye ball can be used to track eye movements. Lately it has been used to control the human machine interface for programming machines.[4] The clinical electrooculogram is an electrophysiological test, in which the potential changes generated across the outer retina and retinal pigment epithelium (RPE) are recorded. This process is done by exposing the retina to successive periods of dark and light adaptation.[5]

An interruption in, or a temporary periodic cessation of the awake state can be referred to as sleep. Worldwide, the prevalence of insufficient sleep is 20% among adults.[6] Sleep deprivation increases the risk of human-error related accidents.[7] Lack of adequate sleep reduces workplace productivity in industries, public safety, and personal well-being.[8] Sleep deprivation is one of the causes of accidents and catastrophic failures in real world situations.[9] Those who suffer from chronic sleep disorders have difficulty in performing daily functions, have health issues, and compromised quality of life.[10]

Sleep deprivation causes fatigue, sleepiness during day hours, clumsiness and may cause weight loss or weight gain. The cognitive functions of the brain are also affected. The economic impact of accidents that happen because of sleep deprivation is $4.3 billion annually.[11] Motor vehicle accidents are also related to fatigue, drowsiness during driving, and sometimes falling asleep at the wheel.[12] Studies carried out on workers who work in shifts[13], truck drivers[14], medical residents[15] and airline pilots[16] show an increased risk of crashes or near misses due to lack of sleep.

Sleep deprivation causes psychomotor impairments that have been shown to be equivalent to the impairments induced by consuming alcohol, either at or even above the legal limit.[17] For example, in a simulated study of driving performance, lane-keeping ability was impaired in subjects after a night without sleep. This was equivalent to the observations recorded in drunk drivers with a blood alcohol content (BAC) of 0.07%.[18] Similarly, a study conducted on professional truck drivers revealed that performance, accuracy and reaction time were impaired in drivers who had 28 hours of sleep deprivation and were equivalent to those abnormalities found after alcohol intoxication (BAC at 0.1%).[19]

In this research Electrooculography (EOG) was used to measure voltages produced by extraocular muscles during various eye movements to demonstrate whether sleep deprivation did or did not have an effect on the voltages produced during different eye movements.

METHODOLOGY

This descriptive cross-sectional study was based on a group of 17 individuals (8 males and 9 females aged 20±0.8 years) who were medical students at CMH Lahore Medical College and Institute of Dentistry. All study participants volunteered to take part in this study. The study was approved by the ethical review committee of the college. The sampling technique was purposive sampling. The sample size was kept comparable to the sample size already reported in literature for sleep deprivation studies. The inclusion criteria for the experimental group was healthy individuals with a sleep debt of at least 21 hours while the inclusion criteria for the control group was healthy individuals who had slept a minimum of 6 hours the night before the EOG test day. The exclusion criteria for both groups were smoking, co-morbidities and use of stimulants like tea, coffee, energy drinks etc. All study participants were living in the college hostel, and stayed awake in groups of twos or threes to ensure sleep deprivation. One researcher from the team periodically checked the wakefulness of the participants at 30 minutes interval to ensure they were awake. The procedure was explained to the subjects and an informed consent was acquired from them. The test was performed in a similar manner on each individual, with identical electrode placement to avoid discrepancies in results. BIOPAC data acquisition unit MP36 was used with BioPac Student Lab (BSL) Software version 4.0.0.

Six BioPac disposable vinyl electrodes (ESL503) were used per subject. The electrodes were placed according to the BSL user manual directions on the temple, forehead and cheeks. The leads connected the electrodes to the BioPac acquisition unit. The software was calibrated for each subject individually before the start of the test. The subjects were made to sit comfortably in the chair and asked to follow a dot on the screen and trace its circular path without blinking, talking or moving his or her head. Once calibration was done the subject was asked to perform a few movements of the extraocular muscles which gave rise to a voltage which was recorded in the form of graphs.

The following steps were asked to be followed by the subjects in order to record their electro ocular potentials:

- For horizontal movements, the subjects were asked to fixate on a point on a pendulum moving within their visual field and trace it's to and fro movement with their eyes without blinking, moving their head or talking. The subjects were then asked to close their eyes and imagine a pendulum moving within their visual field and follow its course. This was the simulated pendulum technique.
- For vertical movements the subjects were asked to fixate at the tip of a pen moving in vertical direction within their visual field and follow it's up and down movement. The subjects were then asked to close their eyes and imagine that the pen was moving within their visual field and follow its course. This was the simulated technique.
- For saccadic movements the subjects were asked to read a short passage silently followed by a long passage and then by reading aloud the same long passage.

Movements were recorded and analysed on BioPac Student Lab Software (BSL version 4.0.0). Values computed for voltage, time and velocity were calculated by the BSL software. Data was analysed using SPSS-20. Descriptive statistics were reported in Mean±SD for all parameters.

RESULTS

Of the 17 medical students, there were 8 (47.1%) males and 9 (52.9%) females. The age for the participants was 20±0.8 years. The sleep debt was 27.3±3.15 hours for the experimental group and hours slept for control group were 8.2±1.5.

The voltage generated during eye movement in various manoeuvres is summarized in Table-1. The time taken by the experimental and control groups for reading a simple English passage silently (reading silently 1), a complex English passage silently (reading silently 2) and reading aloud is summarized in Table-2. Table-3 shows the mean velocity of saccadic eye movements during reading these passages.

Table-1: Mean EOG voltage (p-p) in mV when eyes were following a fixation point (Mean±SD)

	Experimental Group	Control Group
Horizontal axis		
Pendulum tracking	1.10±0.17	1.11±0.31
Simulated tracking	1.18±0.38	1.23±0.33
Vertical axis		
Vertical tracking	0.29±0.1	0.92±0.57
Simulated tracking	0.51±0.23	0.92±0.62

Table-2: Time taken in seconds (delta-T) while reading a passage (Mean±SD)

	Experimental Group	Control Group
Reading silently (1)	14.68±3.77	11.3±2.56
Reading silently (2)	35.41±8.16	33.29±6.30
Reading aloud	46.31±6.14	41.89±3.91

Table-3: Velocity of saccadic eye movements in mV/sec during reading a passage (Mean±SD)

	Experimental Group	Control Group
Reading silently (1)	1.14±0.24	0.98±0.22
Reading silently (2)	1.03±0.36	0.97±0.51
Reading aloud	0.27±0.16	0.67±0.55

Figure-1 shows the comparison of the voltage generated in the extraocular muscles during pendulum tracking, during simulated pendulum tracking, vertical tracking and simulated vertical tracking. It is evident that the extraocular muscles of experimental group generated lesser voltage when compared to those of the well-rested control group. There was a slight decrease in overall mean voltage of the experimental group in the pendulum tracking and simulated pendulum tracking.

Figure-2 shows the comparison of the time taken by the two groups to read two passages, first silently and then loudly. As shown in the graph, the control group can read the passages much more quickly than the sleep deprived subjects. A delay in saccadic movements was noted in experimental group as compared to control, as demonstrated by the increased time to read the passage by the experimental group.

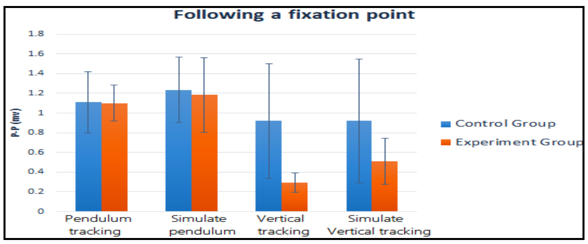

Figure-1: Comparison of the voltage generated in extraocular muscles during tracking movements in experimental and control groups

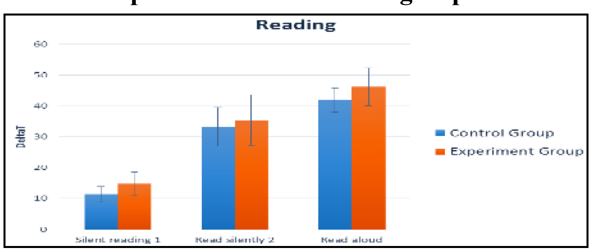

Figure-2: Comparison of time taken by the two groups to read two passages

DISCUSSION

Electromyogram (EMG) and electrooculogram (EOG) are the two tools in electrophysiology that are commonly used parameters in the biomedical industry for development of electronic devices that can be controlled by the paralyzed or diseased patients such as electronic wheelchairs and hospital alarm systems.[20] Unfortunately, the presence of data acquisition systems in the undergraduate physiology laboratories is underutilized as staff and faculty are not trained to demonstrate these physiological concepts to the students. Neurophysiology of the eye is a difficult subject to grasp at the level of 2nd year MBBS, and this study is one of its kind in utilizing this parameter but the equipment at our institution helps make the concept easier for the undergraduate students.

Movements of the eye ball during wakefulness are either pursuit movements or saccadic movements. Pursuit movements occur when a moving target is followed smoothly by the eyes. Saccades happen during reading or when there is a change of gaze toward a target or when multiple fixation points are used quickly. Saccadic movements are not smooth but occur as distinct jumps. These jumps are rapid and accurate.[21] In the present study, we have demonstrated the effects of sleep deprivation on pursuit movements and saccadic movements in the form of pendular tracking, vertical tracking and reading. The participants who were sleep deprived showed a marked decrease in the voltage generated during these eye movements. As reported previously, sleep deprivation has a detrimental effect on the extraocular movements. In a study conducted in 2003 in USA on commercial drivers between the ages of 22 to 60 years, it was reported that sleep deprivation delays the velocity of saccadic eye movements.[22] This change in the velocity of saccadic eye movements is also observed in our study, as the velocity of movements in the control group is faster than that of the experimental group. In another study conducted in Rome, it was demonstrated that 40 hours sleep deprivation is associated with impairment in saccadic and pursuit eye movements.[23] However, in our study we have demonstrated these effects with a much lesser duration of sleep deprivation. The time taken by the subjects of the experimental group to read an English passage silently, and then reading it out loud was also shown to be longer in our study. To our knowledge, no other study has previously commented on this duration.

Sleep deprivation, as reported previously, causes serious effects on the health of a person. In the modern era, sleep deprivation is a common issue among students of various colleges and among employees of various professions. It has been demonstrated in 2017 at Imperial College London that the loss of sleep affects the physical and cognitive performance of students.[24] Use of media and electronic gadgets has been reported to be an important contributor to sleep deprivation in students. Educational researchers and parents should be more careful and need to pay attention to student's sleep and to improve both quality and quantity of sleep.[25]

CONCLUSIONS

Electro ocular potentials generated during eye movements are affected by the amount of sleep. Lack of sleep in undergraduate students is linked to a reduced voltage in EOG and a longer time taken during saccadic eye movements and horizontal and vertical tracking.

RECOMMENDATIONS

Students can be guided towards having adequate sleep and interventions be introduced after a factor analysis of reasons of deprivation in order to prevent the adverse effects of sleep deprivation on normal body function.

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SH: Procurement of equipment, traning of staff, study design, proof reading and final approval

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