Original Article / Özgün Araştırma

Assessment of the Effects of Light and Sound Impulses on the Electrical Potential of the Eye and Ocular Muscles

Görünür Işık ve Ses Uyarılarının Göz Elektriksel Potansiyeli ve Oküler Kaslarda Oluşturduğu Etkilerin Elektrookülogram ve Elektromiyogram ile Değerlendirilmesi

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Abstract

Objective: The aim of this study is to determine the effects of visible light on the electrical potential of the eye and facial/ocular muscles using electrooculography (EOG) and the effects of visible light and sound stimuli electromyography (EMG). We also intend to assess normal human electrical activity by documenting the alteration in EOG and EMG signals.

Materials and Methods: The EOG was recorded for 25 healthy individuals (10 women and 15 men) in compliance with the International Society for Clinical Electrophysiology of Vision standards. In addition, visible light and sound stimuli were applied to the test subjects during facial and/or ocular EMGs recording. Further, the data were analysed using SPSS 12.0 statistical program.

Results: In normal healthy subjects, the amplitudes of the EOG potential during the dark period (men 0.69±0.09; women 0.67±0.11) were lower than that in the light period (men 1.29±0.18; women 1.35±0.15). The mean values of Arden ratio were 2.06±0.11 and 2.14±0.12 for men and women, respectively. Although visible light stimuli enhanced the EMG signals in the facial and/or ocular EMG, the click sound did not cause significant alteration in the EMG signals.

Conclusion: Visible light has been reported to have beneficial effects on the EOG and facial/ocular EMG signals in normal healthy individuals. However, click sound has no effects on the facial/ocular EMG. We therefore propose that facial/ocular EMG and EOG measurements possibly have the potential to diagnose various disorders in clinics.

Öz

Amaç: Görünür ışık uyarılarının göz elektriksel potansiyeli ve fasiyal/oküler kaslarda oluşturduğu etkilerin elektrookülogram (EOG) ve ışık uyarılarıyla beraber nötr ses uyarılarının elektromiyogram (EMG) olarak değerlendirilmesi amaçlanmaktadır. Bu çalışmada ayrıca, EOG ve EMG sinyallerinin normal insan elektriksel aktivitesini belirlemeyi planladık.

Gereç ve Yöntemler: EOG 25 sağlıklı bireyde (10 kadın ve 15 erkek) Uluslararası Görme Klinik Elektrofizyolojisi Derneği standartlarına göre yapılan ölçümlerle saptandı. Deneklere görünür ışık ve ses uyarıları uygulandı. Elde edilen veriler SPSS 12.0 istatistik programı kullanılarak değerlendirildi.

Bulgular: Normal sağlıklı bireylerin EOG ölçülen potansiyelin genliği karanlık dönem (erkek 0,69±0,09; kadın 0,67±0,11) aydınlık dönemdekinde (erkek 1,29±0,18; kadın 1,35±0,15) daha düşük bulundu. EOG potansiyellerinden hesaplanan Arden oranı ise erkekler 2,06±0,11 ve kadınlarda 2,14±0,12 belirlendi. Işık uyarılarının fasiyal ve oküler EMG ölçümlerinde EMG sinyalinin genliğini artırırken klik ses uyarısının anlamlı bir potansiyel farkı oluşturmadığı saptandı.
Sonuç: Normal sağlıklı bireylerdeki EOG ve fasiyal/oküler EMG ölçümlerine görünür ışığın pozitif, klik ses uyarısının ise EMG sinyallerinde nötr etkisi olduğu gösterildi. Fasiyal/oküler EMG ve EOG uygulamaları çeşitli hastalıkların tanısında olası yarar sağlayacağı görüşündeyiz.

Introduction

Light, which can be defined as radiant energy perceived by the human eye, is a form of electromagnetic radiation that includes invisible rays besides its visible spectrum (1). The wavelengths of visible beams are between 400-770 nm and their energies are between 1.6 and 3.1 eV. Because they reflect or absorb light at visible wavelengths of light, objects appear colored in white light. In biological systems, the energy of absorbed light causes molecules to move to higher energy levels. The beam is scattered in the cornea and is absorbed only by pigments in the retina (2). The electrical potential formed in the eye is homogeneously distributed everywhere in the eye (3). The eye is surrounded by an electrical field and the potential measured from here is proportional to the dipole potential. Electrooculography (EOG) records the voltage difference between the posterior pole of the eye (retina) and the cornea when we electrically accept the eye as a battery. In other words, the dark and light effect on the resting potential between the retinal pigment epithelium and the cone and rod cells is determined by EOG. In the Normal eye, this potential is 6 mV. In other words, EOG measures the potential in the electrical field surrounding the eye through the skin, which is proportional to the sum of all in the electrical field surrounding the eye through the skin, which is proportional to the sum of all the potentials formed and absorbed within the eye. This potential can be changed by anatomical, metabolic, and biochemical changes that may occur in the photoreceptor and pigment epithelium, thus providing nonspecific and indirect information about the functional state of the outermost layers of the retina (4). In practice, since electrodes cannot be placed directly on the retina, the retinal resting potential is indirectly recorded. It has been reported that direct EOG measurements made from the retina for research purposes do not differ between in-direct EOG records (5,6).

The fact that the effects of rays in different wavelengths create changes in these potentials will be able to bring innovations to the use of clinical EOG. Recording the possible effects of visible ray stimuli in facial muscles with electromyography (EMG) simultaneously with EOG will provide information about these muscles. From the facial muscles, m.zygomaticus expresses major positive emotions (happiness, bewilderment, etc), on the other hand, m.corrugator supercili displays negative emotions (resentment, fear, etc). Besides, m.orbicularis oculi palpabraeous lateralis and inferior show positive emotions such as benevolence-joy, m.orbicularis oculi palpabraeous superior and inferior indicates negative emotions such as humiliation-resentment.

Research in the literature has focused on blink movements while studying the effects of sound impulses on electrical potentials in the eye. Matsuo et al. (7) showed that the change in eyelid position during blinking or the movement of the eyelid on the cornea, affects the electrical potential difference between the cornea and retina. For this reason, electrical potentials formed during eyelid movements can be measured by EOG measurements on the skin around the eyes. Contraction of the orbicularis oculi muscle and relaxation of the levator palpebra muscle is responsible for the mechanism that allows eyelid movement (8). EMG and EOG data measured simultaneously after sound warnings were given to facial muscles that have been reported to provide separation of reflex, spontaneous, and voluntary eyelid movements (9-11). Motor nerve (III, IV, VI) damage results in limitations in the vertical and horizontal movements of the eye (12). Intraoperative EOG and EMG measurements were used for monitoring oculomotorius and abducens nerves in skull surgery (13,14).

In this study, it is aimed to evaluate the electrical potential of the eyes and the effects of visible light and sound impulses on the facial muscles with EOG and EMG. Here, the effect of light applied from various angles on the electrical potential in the eye is the desired goal to observe the possible changes that will create in EOG measurements and EMG values. Changes in EMG and EOG values measured as a result of sound warnings (low-intensity noise) will be shown. It is expected that the changes in EOG and EMG that will occur as a result of the combined delivery of light and sound stimuli will be different from the delivery of these stimuli alone.

Materials and Methods

Electrooculography Measurements

EOG measurements were performed in 10 voluntary and pre-informed women (26±10 years) and 15 men (28±14 years). During the EOG measurements, no external warnings were given that could affect measurements when measurements were made. First, disposable silver/silver chloride electrodes are placed longitudinally with the inner and outer canthus of the subject. Subjects were asked to look at the lighting board at a distance of 30 cm with a fixation light on it with only their eyes without moving their heads. After the subjects were placed in front of the panel so that the angle between the two fixation lights and the eyes was 30°, the light flashing allowed the subjects to make a constant amplitude horizontal movement by moving their eyes from one light to another. Changes in potential during these movements (10 seconds per minute) were recorded as microvolts. After a pre-adaptation period spent in a light environment for 10 minutes before starting measurements, eye movements were recorded with the Biopac MP100 Data Analysis System (Goleta, CA, USA) during the 15 minutes dark and 15 minutes light period, respectively.

Statistical Analysis

The data were analyzed with the Acqknownledge 3.8 software (Biopac Systems; Goleta, CA, USA). As an evaluation criterion, the Arden ratio, the ratio of the Light peak (Lp) to the dark trough (Dt) is used to determine the normalcy of the results, and the time to reach the highest value measured in light were used (15). Mann-Whitney U test was used in SPSS 12.0 software for statistical analysis.

Electromyography Recordings

EMG recording was performed using multi-use silver/silver chloride electrodes placed anatomically orbicularis oculi, zygomaticus major and corrugator supercilii muscles on the subject's faces. During this recording, full contact of the electrode to the skin surface was achieved by using the gel used for EMG. Superficial EOG and EMG are non-invasive methods. Due to the use of surface electrodes adhered to the skin, Ethics Committee approval was not obtained. The data was recorded with the Biopac MP100 Data Analysis System and analyzed with the Acqknownledge 3.8 software.

Results

The records taken in during the dark period of the EOG and showing the change in the amplitude of the

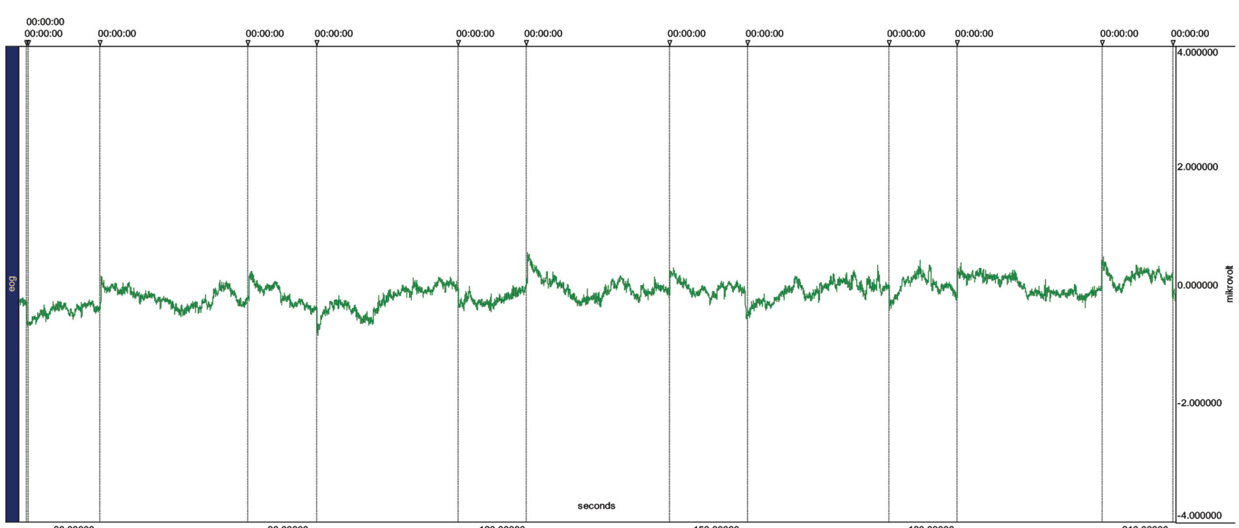

Figure 1. The amplitude (mV) of the EOG recordings of saccadic movements of the eye over time (sec)
EOG: Electrooculography

saccadic movements of the eye over time are shown in Figures 1 and 2. The potential changes of 10 seconds recorded every minute during EOG recordings are seen in Figure 1. The potentials obtained in dark and light periods are shown in Figure 2. In eyes adapted to darkness, it gradually descends to a low level. On the other hand, in light-adapted eyes, the peak rises to the highest point. Our EOG amplitude recordings in darkness were found to be lower than recordings in light.

For male and female participants, Table 1 shows the time to reach the highest value measured in light with Arden ratios by calculating saccadic motion amplitudes in the dark and light periods. The Arden ratio was found to be lower in men than in women. As a result of statistical analysis, a significant difference was found between male and female values ($p<0.05$).

EMG recordings of zygomaticus major and corrugator supercilii muscles are shown in Figure 3 depending on the emotional changes of the subjects.

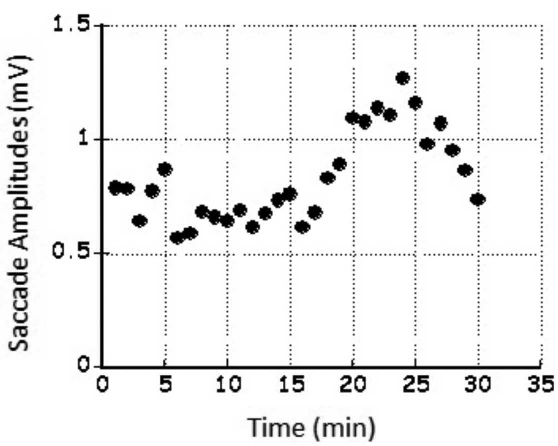

Figure 2. Saccadic motion amplitudes in EOG (First 15 min shows dark period-second 15 min shows light period)

EOG: Electrooculography

There is an increase in EMG potentials obtained in the zygomaticus major muscle when positive emotions are intense, (i.e. smiling), on the other hand, EMG potentials are increased in the corrugator supercilii muscle when negative emotions are intense (i.e. angry and raising an eyebrow). However, there were no changes when subjects stimulated with sound effects.

We observed that blinking caused more increase in

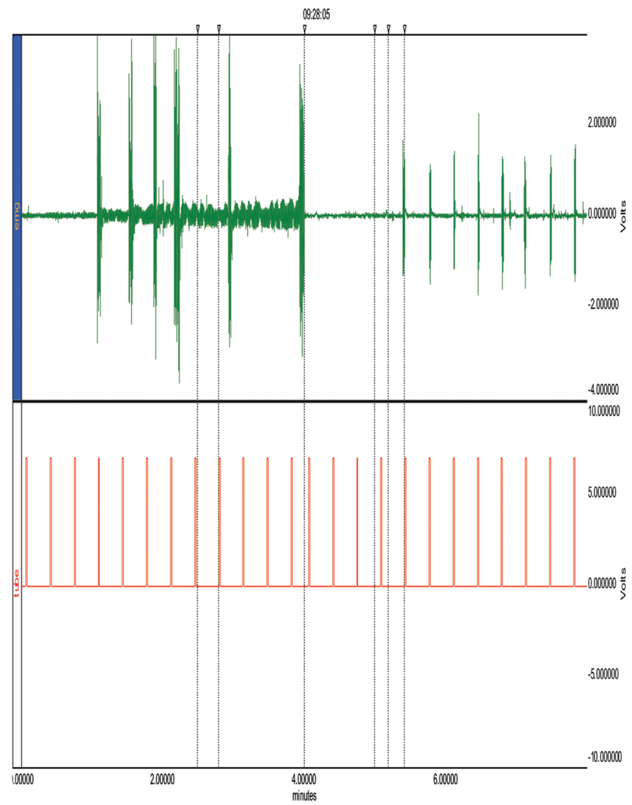

Figure 3. The EMG recordings of the zygomaticus major and corrugator supercilii muscles. The amplitude (mV) changes over the recording period (min)

EMG: Electromyography

Table 1. Time to reach the highest value measured in light with Arden ratios by calculating saccadic motion amplitudes in the dark and light ($p<0.05$)

Sex	Mean saccadic amplitude (mV) (Dark period)	Mean saccadic amplitude (mV) (Light period)	Arden ratio	Time to reach the highest value measured in light (minimum)
Male (n=15)	0.69±0.09	1.29±0.18	2.06±0.11*	9.25±1.34 min
Female (n=10)	0.67±0.11	1.35±0.15	2.14±0.12*	8.13±1.15 min

EMG signal than eyebrow lift movement in orbicularis oculi muscle, however, we did not see any changes in EMG when subjects smiled. Also, it was observed that the click-shaped sound stimulation applied did not lead to significant changes in the EMG signal (Figure 4).

EMG recordings taken from the orbicularis oculi muscle is seen in Figure 5. 5 mV (80 dB) sound signal with a tubephone ear tube electrode is given for 1 second with 13 seconds intervals, while for the first 75 seconds, the subjects were not given other than a sound warning. Then both sound and light warnings were issued. While no significant changes occurred due to sound stimulation, there was an increase in the EMG signal due to light stimulation (Figure 5).

Discussion

The EOG consists of two potentials: The standing potential (resting potential, dark phase, dark current) which is evoked by moving the eyes in the dark and originates from the retinal pigment epithelium, and the light potential (light rise) which is evoked by moving the eyes in a lighted environment and originates from the photoreceptors. Clinical applications were described first by Arden (15) in 1962, who realized that the most valuable information was the comparison of the amplitudes under light and dark-adapted states. The Arden ratio, the ratio of the Lp to the Dt is used to determine the normalcy of the results. An Arden ratio of 1.80 or greater is normal, 1.65 to 1.80 is subnormal, and <1.65 is significantly subnormal. The most common use of the EOG is to confirm Best's Vitelliform Dystrophy Disease (4). In accordance with the criteria of the International Organization for Clinical Electrophysiology, which standardizes electrophysiological measurements in the eye, normal values for EOG measurements were determined in our electrophysiology laboratory. In our experiment, we found out that the normal mean Arden ratio from both sexes. On the other hand, there was a significant difference between men and women. We conclude that more experiments need to be done to compare Arden Ratios in men and women.

Bradley and Lang (16) (2000) reported that the EMG signal received from the corrigator muscles increased with the application of unpleasant sounds

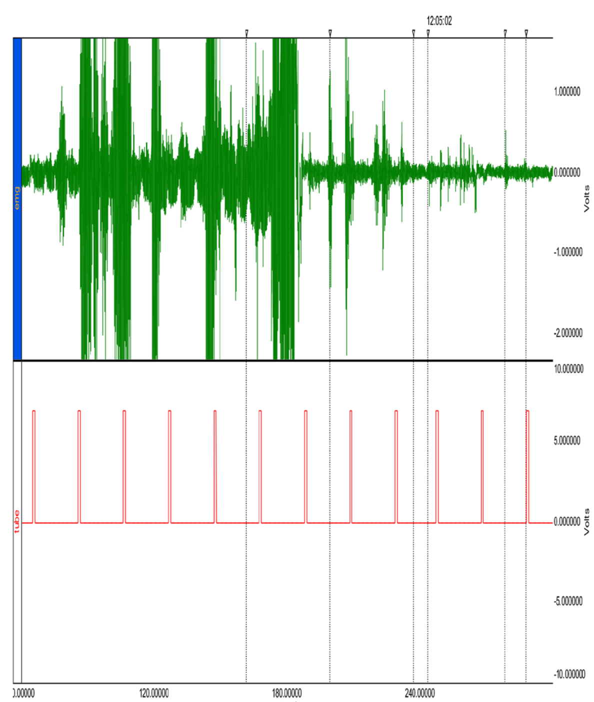

Figure 4. The EMG recordings of the orbicularis oculi muscle. The amplitude (mV) changes over the recording period (min)

EMG: Electromyography

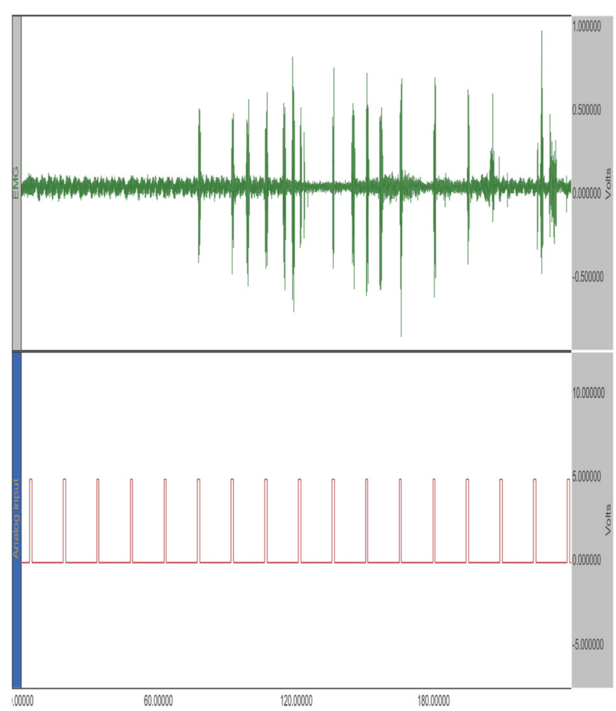

Figure 5. Effects of light and sound stimulation on EMG signals in orbicularis oculi muscle

EMG: Electromyography

such as bombs, screams, etc, and they also stated that EMG signals amplitude less increased in facial muscles when compared to corrigator muscles. They also showed that neutral sounds are ineffective on the facial EMG signals. Similarly, in our study, we observed negative emotions increased the EMG signals in corrigator supercili muscles and positive feelings like smiling had a positive effect on the zygomaticus major muscle. We did not see any changes in the neutral click sound on facial muscle EMG signals amplitude.

Conclusion

In this study, (1) EOG measurement standards have been established in our laboratory (2) light stimuli have been shown to have a positive effect on EMG signals (3) positive and negative affections have been shown to lead to changes in EMG signaling in different facial muscles, (4) neutral sound signals have been shown to have no effect on EMG. As a result, we believe that our preliminary study will increase the use of EOG and facial EMG measurements in the future.

Ethics

Ethics Committee Approval: Due to the use of surface electrodes adhered to the skin, Ethics Committee approval was not obtained.

Informed Consent: Patient consent was not obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: M.D.B., R.O.E., Design: M.D.B., R.O.E., Supervision: A.Ç., R.O.E., Fundings: M.D.B., Materials: M.D.B., Data Collection or Processing: A.Ç., M.D.B., R.O.E., Analysis or Interpretation: A.Ç., Literature Search: A.Ç., R.O.E., Writing: A.Ç., Critical Review: A.Ç., R.O.E., M.D.B.

Conflict of Interest: No conflict of interest was declared by the authors.

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