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DEVELOPMENT OF A DEVICE FOR STIMULATION OF OPTOKINETIC NYSTAGMUS TO SUPPORT ASSESSMENT AND REHABILITATION OF POSTURAL BALANCE

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Abstract: *Vectoelectronystagmography records eye movements to assess the labyrinth and its relationship to the central nervous system. This test allows the identification of balance disorders and the side, type and extent of injury. The optokinetic test is a neuro-ophtalmologic tool that is used in a vectoelectronystagmography battery to reveal evidence of the central nervous system's dysfunction. Optokinetic nystagmus is a rhythmic eye movement, produced during the visualization of moving targets that fills at least 80% of the visual field. In normal individuals, the optokinetic nystagmus is symmetrical in both clockwise and counterclockwise directions of stimulation. There are several techniques for obtaining optokinetic nystagmus. In Brazil, partial visual field devices, including LED bars and small-motorized drums, are used to produce eye movements close to that of optokinetic nystagmus. However, due to the fact that only a small portion of the visual field is stimulated, such equipment~~s~~ produces nystagmus of small amplitude, but not the true optokinetic nystagmus.This study developed and tested a device for eliciting clockwise and counterclockwise optokinetic nystagmuses at varying speeds, from the projection of visual stimuli filling the visual field of the individual with white and black stripes. Nystagmuses were acquired using the LED bar and the developed device in the velocities of 20, 40 and 60 degrees per second, in both clockwise and counterclockwise directions. Repeated measures ANOVA was used to compare nystagmuses acquired on both devices. Participants were 34 adults from both sexes, with no balance disorders, with mean age of 25.44 years. Results showed no difference between sexes. We observed higher mean amplitude nystagmus in all speeds and in both directions using the new equipment. It showed to be better appropriate to promote stimulation of full visual field, thus contributing to the identification of patients with central vestibular dysfunction in vectoelectronystagmography testing.*

Keywords: *Optokinetic Nystagmus, Electronystagmography, Dizziness, Postural Balance, Photic Stimulation*

1. INTRODUCTION

Body balance is the ability of human beings to remain in the upright position or perform acceleration and rotation movements of the body without swaying or falling down (Flores *et al*., 2011). Maintaining balance requires coordination of input from multiple sensory systems including vestibular, somatosensory, and visual systems. (Bankoff and Bekedorf, 2007). A disorder between these systems is commonly manifested by dizziness, an impairment of spatial perception and instability characterized by body movement or the sensation of surrounding movements (Colafêmina, 2003).

Vestibular testing analyzes the labyrinth function and its relationship with other systems (Lourenço *et al*., 2005). The exam confirms data gathered in history, provides information about the site of injury (central, peripheral or mixed), type and extension. It is comprised of static and dynamic balance tests; positional and positioning testing; and vectoelectronystagmography (VENG), that consists on the evaluation of the vestibular system and its relationship with the central nervous system by measuring involuntary eye movement (nystagmus) while the subject's balance system is stimulated in different ways (Caovilla, *et al*., 1999). From properly positioned electrodes, nystagmuses are captured, allowing the recording and analyzing of their characteristics (Shepard e Schubert, 2008). There are four main parts of VENG: positional testing, ocular motility testing, rotational testing and caloric testing. Ocular motility testing adds important information regarding a central pathways' function, and three principal ocular control events are evaluated: saccade testing, smooth pursuit tracking and optokinetic nystagmus.

Optokinetic nystagmus is a physiological eye reflex elicited when a repetitive series of optical stimuli passes through the retina. The speed and extent of optokinetic nystagmus depend on the speed of the presented stimulus. Generally the stimulus used is a drum composed of white and black vertical strips placed one meter in front of the examinee. The drum rotates in clockwise and counterclockwise directions triggering nystagmus to the right and left, respectively, in normal subjects (Gyo, 1989). The optokinetic nystagmus is an established neurological and neuro-ophthalmological research tool, and is also important in the conventional VENG tests since it determines central vestibular changes when the results are altered (Jacobson e Shepard, 2008). In normal individuals, optokinetic nystagmus is symmetrical in the comparison between clockwise and counterclockwise directions (Fife, *et al*., 2000).

Optokinetic system is closely related to the vestibular system, since their real goal is not to follow the movement of a visual scene while the observer remains stationary, but supports the vestibular system during rotational movements, producing appropriate eye movements. Both systems share the same goal of trying to keep the speed of the eyes but in the opposite direction to the speed of the head (Moreira e Maudonnet, 1998).

The optokinetic nystagmus can be obtained from a drum with white and black stripes, light bars (LEDs) or through projection screens, occupying a greater part of the visual field. In Brazil, the most commonly used devices are the drum and the LEDs bar, but in international otoneurology services optokinetic nystagmus is obtained through large screens. The LEDs bar produces a series of dots which move to the right or to the left, but they fill only a small area of the visual field, which ultimately results in a similar eye movement (smooth pursuit tracking) but not the same as optokinetic nystagmus. Kveton et al. (1999) conducted a study proving the effectiveness of screens to optokinetic projection on the light bars.

Authors reported that optokinetic nystagmuses are reflexive eye movements during the visualization of moving objects that fill 80 to 90% or greater of the visual field of view. These same authors conducted a study showing that stimulation using small devices provides a higher number of false positives compared to an optokinetic stimulator of full visual field, and questioned the clinical value of partial visual stimulators used at VENG tests (Kveton et al. 1999).

There are many techniques to obtain the optokinetic nystagmus, but not all are suitable. In Brazil, a variety of partial visual field devices are used to produce an eye movement that look like optokinetic nystagmus, including light bars with LEDs and small motorized drums. However, due to the fact that only a small portion of the visual field is stimulated, such equipments do not produce a true optokinetic nystagmus.

This study becomes necessary, since the techniques currently used in Brazil for obtaining optokinetic nystagmus are not suitable and therefore do not allow for the production of appropriate eye movements.

This research aims to develop and evaluate a device for the stimulation of optokinetic nystagmus from the projection of white and black bands on a screen situated in front of the patient, in order to promote the stimulation of the entire visual field, especially the retina, contributing to the development of most suitable technology for evaluating the balance, and allowing the identification of patients with central vestibular dysfunctions. There is a deposit of device patent application made by Coordenadoria de Transferência e Inovação Tecnológica of UFMG.

2. DEVICE OF STIMULATION OF OPTOKINETIC NYSTAGMUS

The developed device consists of a detachable chair seat, a pedestal with adjustable height, a motorized system with rotation and direction regulation and also the rotating light emitting bands. The device was designed to be collapsible, so it may be transported to various environments for the diagnosis and rehabilitation of patients as indicated in Fig.1.

The seat can be removed, allowing the patient to remain standing or sitting. It also has support bars for the patient to hold on if necessary. Close to the chair there is a pedestal with adjustable height so that the top of the device (motorized system and rotating light emitting bands) can be positioned according to the height of patient (sitting or standing).

At the top of the pedestal is the motorized system constituted by an AC/DC motor coupled to a gears reduction system which enables the rotational movement of the light emitting bands. The system has regulation of rotation speed and spin direction, and also an on/off switch of the light source (fluorescent lamp), according to the established protocol. The motor system control consists of a console with a changeover switch that is positioned to obtain either direction of rotation, a potentiometer that controls the desired level of rotation of the light emitting bands and an on / off switch of the light source. This button works in parallel with another on/off switch of the light source that can be turned on directly by the patient according to the established protocol.

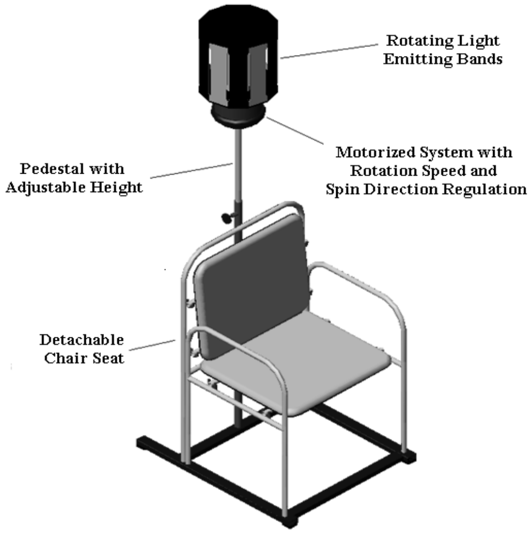

Figure 1. Device for stimulation of optokinetic nystagmus

The light emitting bands uses a central light source obtained by the use of a white compact fluorescent lamp (cold light). The lamp stands still and the light emitting bands does a rotational motion at various speeds in clockwise and counterclockwise directions according to the established protocol, producing the movement of the light bands.

The emitter projects moving light bands on a large screen (180^o amplitude) preferably in a cylindrical surface area (best option) creating a visual field suitable to optokinetic nystagmus. The dimensions of the light emitting bands have been developed in order to allow enough space for placing the compact fluorescent lamp and also to the white stripes (light) and black stripes (no light) be as uniform as possible.

The number of white and black bands obtained around a 360° angle will depend on the number of slots for the passage of light from the fluorescent lamp laid down in the emitter, depending on the necessity as show in Fig. 2.

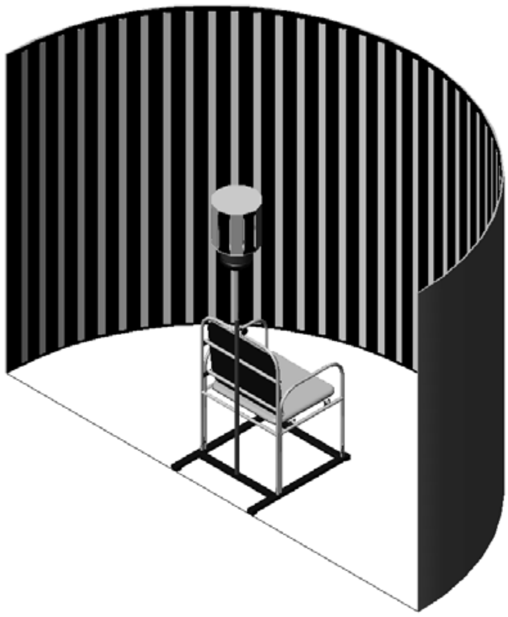

Figure 2. Projection of light bands in a cylindrical 180° surface screen.

For proper implementation of the device for stimulation of optokinetic nystagmus the test or treatment environment should be as free from other light sources (preferably dark). The device can also be used without the use of the light source (using ambient light) causing the patient to look directly to the emitter in a similar manner as the drum motion system.

The rotating light emitting bands developed is constituted by two polyhedral bodies with 12 concentric faces (internal and external) in which there are twelve radially aligned slots that allow the passage of light to create the luminous bands.

The generation of light bands is obtained from the diffraction of light that passes through the slots of internal and external polyhedral bodies, creating new light sources in phase (coherent sources). This generates in the screen light regions obtained by constructive interference of the sources (white stripes), interspersed with regions without light obtained by destructive interference of the sources (black stripes). The rotating light emitting bands in question generates 24 white stripes (light) and 24 black stripes (not light) around 360°.

The internal polyhedral body is found inside the light source and has its surface painted in white in order to reflect light. Its external surface is colored in black to prevent reflection of light. In the upper and lower ends of the internal polyhedral body, there are shields that prevent the passage of light. Then, the light from the light source will pass only through the slots made in the vertices of the internal polyhedral body.

In the external polyhedral body the inner surface was also painted in black to prevent reflection of light and its outer surface has white and black color faces alternately (similar to a drum system). In the upper and lower ends of the external polyhedral body, there are also shields that prevent the passage of light. Thus the light from the light source will pass only through the slots made in the external vertices of the polyhedral body. Figures 3 and 4 illustrate the text.

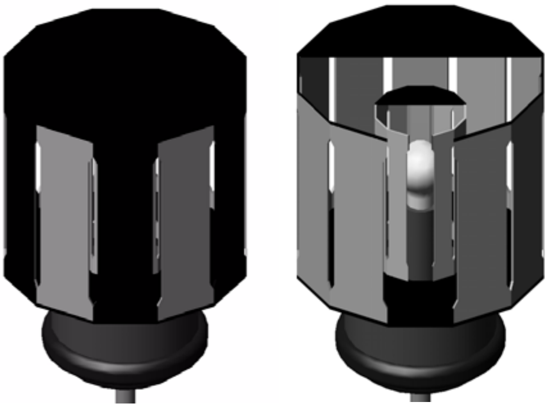

Figure 3. Assembling and partial section of the rotating light emitting bands.

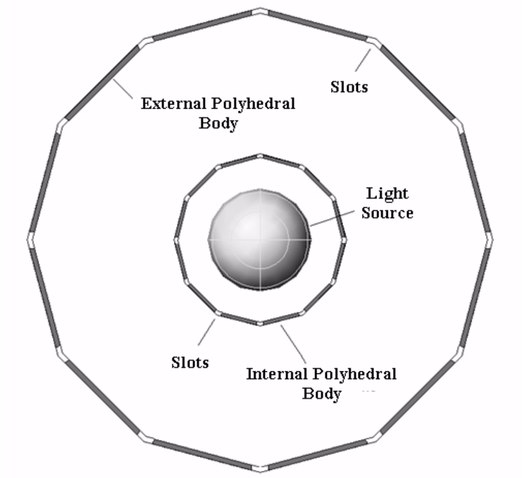

Figure 4. Schematic top view of the rotating light emitting bands.

2.1 Evaluation of the device for optokinetic nystagmus stimulation

A preliminary assessment of the device for stimulation of optokinetic nystagmus was conducted from an analytical study with a convenience sample. The research project was approved by the Ethics Committee of Federal University of Minas Gerais (UFMG) under number 178537-13. Data were collected at the Audiology Service in São Geraldo Hospital/Clinics Hospital of UFMG. Students and staff of UFMG volunteered to participate in the study. They were informed about the purpose of the study, its procedures, risks and benefits, and all signed the consent form. Initially a short questionnaire was completed as an exclusion method for individuals with current or past complaints of balance disorders and hearing loss, evidence or history of cognitive, neurological, motor or ophthalmological impairment. The inclusion criteria were individuals aged minimum 18 years, of both genders, who agreed to participate and signed the informed consent, and who did not have current or previous history of dizziness and vertigo. After completing the questionnaire, the subject sat on the chair in a comfortable position for the exam. They had their skin around the eyes and forehead cleaned, and the electrodes were placed with electrolyte gel and fixed with adhesive tape. A Contronic® version 5.1 vectoelectronystagmography equipment was used. The nystagmus were acquired in three speeds: 20º, 40º and 60º per second in clockwise and counterclockwise directions, tested first with the LEDs bar and subsequently with the developed device. The support of the LEDs bar was placed one meter away in front of the chair and carried out at eye level for each participant, and then instructions were given to the participant to observe the bright dots that were in the middle of the bar, counting them mentally. The participants were also informed that the speed of the dots would be increased gradually. Then the light was turned off and the test began with the dots going in the opposite direction at three speeds. Eye movements were captured by the electrodes and stored in the computer for analysis. The acquisition was the same however white and black stripes were projected on a full visual field through the device, with the chair situated one meter from the wall. The participants were told to mentally count the black stripes that passed in front of them. Figure 5 shows the assembly used in the evaluation of the device for stimulation of optokinetic nystagmus.

Figure 5. Assembly used in the evaluation of the device for stimulation of optokinetic nystagmus.

The slow phase velocity (SPV) is the measure unit of nystagmus and registers the eye movement (in degrees) during time as shown Fig. 6 and Eq. (1). The SPV was then calculated in each velocity and direction, considering at least 3 nystagmuses to get the average of each tracing. Data were released in a spreadsheet of Statistical Package for the Social Sciences (SPSS) program, version 17.0 and descriptive statistics including mean, median, standard deviation, minimum and maximum were used to describe the responses obtained for each nystagmuses elicitation strategy. A comparison between data obtained with each piece of equipment was initially performed using a repeated measures ANOVA for strategic factors (full screen and LEDs bar) and conditions (20º/s, 40º/s e 60º/s to the right and left). When statistically significant differences were found, post hoc tests were used to identify differences between pairs. For all analyses a significant level of α=0.05 was considered.

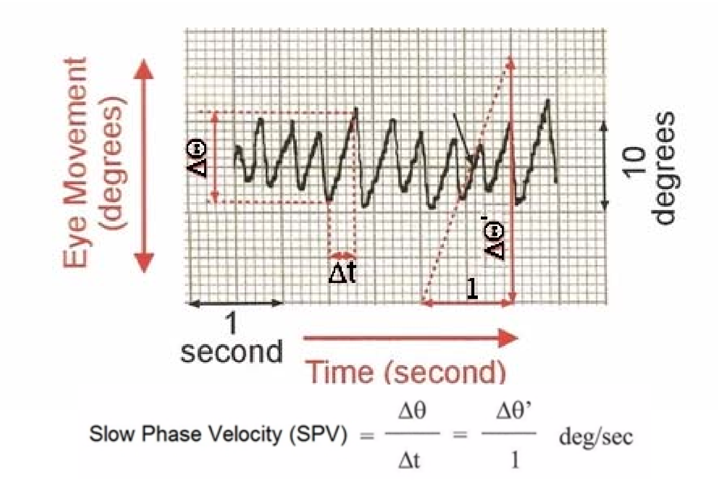

Figure 6. Calculation of the slow phase velocity (SPV)

$$SPV = \Delta\Theta / \Delta t = \Delta\Theta' / 1 \text{ (deg / sec)} \tag{1}$$

2.2 Results

The device was tested in 34 adults with no balance disorders, 17 men and 17 women, with a mean age of 25.44 years. There was no significant difference in the comparison between the means of SPV obtained for men and women, at all speeds and directions using ANOVA. Table 1 shows descriptive statistics of the data obtained in the sample.

Table 1. Descriptive statistics of data in the sample

Results	LEDs bar						New Device					
	SPV (deg/sec) Right			SPV (deg/sec) Left			SPV (deg/sec) Right			SPV (deg/sec) Left		
	20°/s	40°/s	60°/s	20°/s	40°/s	60°/s	20°/s	40°/s	60°/s	20°/s	40°/s	60°/s
Median	15	16	14.5	13	15	15	22	26.5	29	26.5	30.5	33
Mean	15.38	17.97	17.29	14.12	18.50	17.76	28.68	33.62	32.35	27.32	33.88	36.50
SD	5.16	8.61	8.59	4.72	8.15	10.23	15.39	17.23	18.74	9.83	14.79	17.77
Min	8	6	4	8	6	4	8	14	10	10	10	8
Max	30	36	42	29	35	45	95	100	101	46	67	82

Legend: SPV: slow phase velocity; SD: standard deviation; Min: Minimum observed value; Max: Maximum observed value.

The differences in nystagmus amplitude observed with the acquisition using the LEDs bar and the new device at three speeds may be ascertained in Fig. 7.

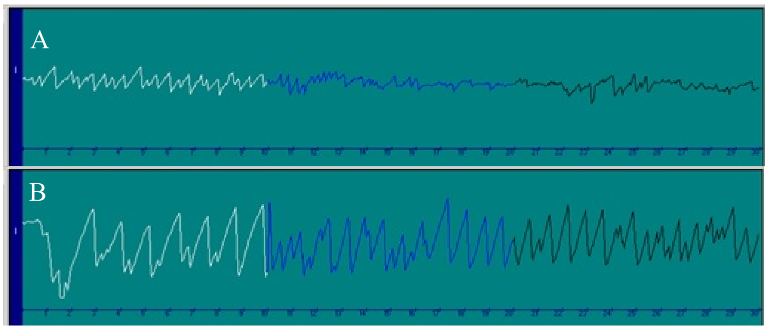

Figure 7. Nystagmuses obtained for the same individual, at three speeds (20°/s in white, 40°/s in blue and 60°/s in black); (A) using the LEDs bar; (B) using the developed device.

Statistical analysis showed a statistically significant difference in the SPV comparison of nystagmuses obtained with LEDs bar and the device, with the largest amplitudes found for the new device at the higher speed of 60°/s. Table 2 show comparison between SPV means obtained to the right and left at all speeds.

Table 2. Comparison between SPC means obtained to the right and left at all speeds.

Direction	Velocities	Strategy	SPV (Mean)	p-value
Right	20°/s	LEDs Bar	15,38	0,001*
		Device	28,68	
	40°/s	LEDs Bar	17,97	0,000*
		Device	33,62	
	60°/s	LEDs Bar	17,29	0,000*
		Device	32,35	
Left	20°/s	LEDs Bar	14,12	0,000*
		Device	27,32	
	40°/s	LEDs Bar	18,50	0,000*
		Device	33,88	
	60°/s	LEDs Bar	17,76	0,000*
		Device	36,50	

Legend: SPV: slow phase velocity; * Statistically significant p-value (Post hoc analysis)

The developed device produced a greater amplitude of nystagmuses when compared to the amplitude obtained with the LEDs bar. This allows us to infer that the new device boosted stimulation of the largest part of the visual field. According to Kveton et al. (1999), LEDs bar produces a series of dots which move to the right or to the left, but only fill a small portion of the visual field of the tested individual. This ultimately results in a similar eye movement, but not the real optokinetic nystagmus.

The device will still be tested in individuals with peripheral and central vestibular dysfunctions in order to ascertain its ability to identify patients with central vestibular disorders.

3. CONCLUSIONS

Preliminary results indicated that the developed device for stimulation of optokinetic nystagmus presented proper functioning and showed to be better appropriate to promote stimulation of the full visual field. The developed device may contribute to the identification of patients with central vestibular dysfunction in vectoelectronystagmography testing.

4. ACKNOWLEDGEMENTS

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