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Research Article

Oculomotor Behavior Metrics in Video Oculography. Effect of Age and Sex on the Normative Values for Saccadic Pursuit

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Abstract

The movements of the eye, such as smooth pursuit, saccades and eye tracking are called Oculo Motor Behavior (OMB). Eye tracking is being increasingly used to examine oculomotor behavior (OMB) for visual and neurological health and normative studies like this has relevance in this context.

The test was carried out on a volunteer group of healthy individuals, via an infrared camera, and digital analysis tracking of the pupil. The Oculomotor Saccadic tracking was done for different groups both in Horizontal and Vertical directions and in 2 speeds i.e. 0.3Hz and 0.45Hz. The parameters analyzed were Velocity, Precision and Latency.

Across all the groups, when these parameters were studied, there was a definite influence of age groups but no statistical difference between these values in males and females. The results argue for the necessity of using such normative values in the assessment of OMB metrics in patients of a particular age group, and the necessity for using contralateral assessments in comparing values obtained from individual patients.

Keywords: Oculomotor Behavior; Saccadic Pursuit; Horizontal Saccades; Vertical Saccades; Effect of Age; Effect of Sex

Introduction

Vision is the most precise and important special sense in Humans. Eye movement is a finely tuned ancillary sense, which ensures that the area of interest remains in the fovea, so that the visual attention is focused on that area.

To do this we humans have binocular vision, and a variety of reflexes to support visual fixation in motion such as Vestibulo Ocular reflex (VOR), Vestibular Spinal Reflexes (VSR) and Vestibular Colic Reflex (VCR). These reflexes permit the eye to remain continuously in focus despite head and body movements and in addition have predictive focus on moving objects.

The movements of the eye, such as smooth pursuit, saccades and eye tracking are called Oculo Motor Behavior (OMB). Deficits in the oculomotor system can result in lower visual acuity, changes in visual perception, and reduced visual stability. The oculomotor system can be an indicator of the neurological status of an individual. With the proper measurement of eye movements, scientists and clinicians utilize OMB to indicate neurological diseases [1].

Leigh and Zee, in their classic textbook, describe the clinical examinations of saccades, smooth pursuit, gaze behavior, and eye-head movements among others. Typically, these clinical evaluations involve a “bedside” approach and instruction which include ‘follow the tip of my finger’ and require the physician to detect the salient characteristics of OMB by the naked eye. Consequently, eye movement research suffered from a limitation in that there was a lack of data regarding the reliability of oculomotor metrics [2].

Eye tracking is being increasingly used to examine oculomotor behavior (OMB) for visual and neurological health and wellness with promise in determining characteristics of healthy eyes and in turn a healthy brain. Human eye movements reflect individual and group differences, including the influence of age, sex, medication etc. There is therefore a need for normative testing in this regard for establishment of test standards.

Aims and Objectives

The purpose of this study was to

- To determine the normative values of horizontal and vertical saccadic OMB
- To compare saccadic OMB metrics by age groups and sex groups.

Materials and Methods

The test was carried out on a volunteer group of healthy individuals, who were informed about the need for the test, its noninvasive nature, and shown the test environment and device, prior to obtaining a university approved written consent. It conformed to the Guidelines of the Ethical Review Board as it was noninvasive and did not involve any patient data.

The subjects were excluded from the study if they reported a history of neurological, ophthalmological or otological illness in the past, and if they failed a visual acuity test.

The Eye movement was assessed via an infrared camera, and digital analysis tracking of the pupil using a Balance Eye Device®.

The Oculomotor Saccadic tracking was done for different groups both in Horizontal and Vertical directions and in 2speeds i.e. 0.3Hz and 0.45Hz. The parameters analyzed were Velocity, Precision and Latency.

Velocity was defined as the total angle of eye movement (in degrees) divided by the time taken for saccades (in seconds). Precision as the ratio of first peak amplitude of the pupil to the amplitude of the saccadic target. Latency as the difference between target saccades onset time and pupil saccades onset time.

Equipment used

The Balance Eye® is a nystagmograph device used to measure, record, or visually display the involuntary movements(nystagmus) of the eyeball. It is a vestibular and ocular motor examination platform, used by ENT surgeons, neurologists, vestibular specialists, and audiologists. It gives a graphical representation of the eye position and movement in response to a preset series of ocular and vestibular stimulations.

It comprises of eye tracking goggles, multi interface unit and software modules as well as cloud-based storage and interpretation support. The Balance eye® VNG detects and displays eye position and movement in response to several vestibular stimulations i.e. saccadic test, smooth pursuit, optokinetic nystagmus, caloric tests, and positional tests. It records and analyses the binocular, horizontal and vertical aspects of eye position and movement. It has different components which are goggle, mean well adapter, multi interface unit, and USB cable (Figure 1, 2).

Test details

Oculomotor testing

Saccadic tracking

Saccades are fast eye movements used to attain fixation of a given target. They are quantified using three parameters latency, precision, and peak velocity.

In this test subjects are evaluated in sitting position looking towards the stimulation screen.

Figure 1: Balance Eye®, a nystagmograph device used to measure, record, or visually display the involuntary movements (nystagmus) of the eyeball.

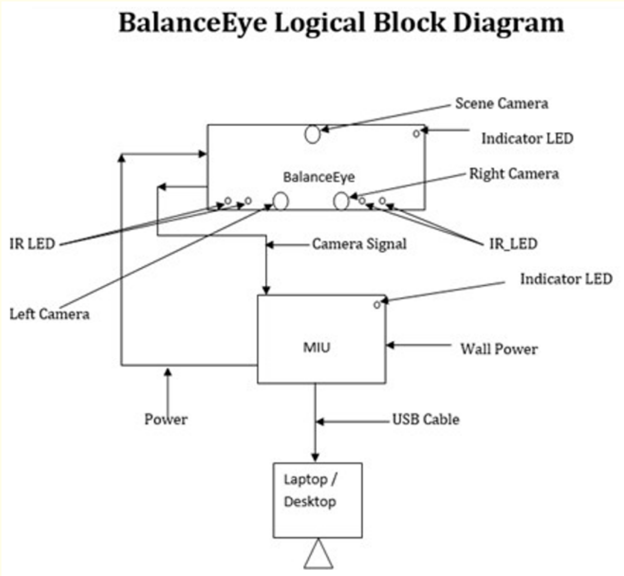

Figure 2

For Horizontal saccades test (HS) subjects were requested to track, after a countdown for preparedness, commencing at the centre of the screen, before moving their eyes back and forth between 2 dots. The aim is for the subject to stare at each dot on the left and right of the screen as rapidly and precisely as possible. Dots turn green on the screen when participants eyes fix on the targets. The Test lasts for 20 seconds. It enables calculations of target accuracy, saccade percentages, and fixation percentages.

The Vertical saccades test has the same protocol as that of the Horizontal saccades but is performed in a vertical plane instead of horizontal.

Results

There were more males than females in our study groups. We classified them arbitrarily age wise in three groups, below 30 years, between 30 - 45 years and above 45, both in the test group for 0.3

Hz and 0.45 Hz in horizontal saccades (Table 1a, 1b) and in the vertical saccade testing groups (Table 2a, 2b).

Test name	Variables		n (%)
0.30Hz Horizontal	Gender	Male	45 (71.4)
		female	18 (28.6)
	Age Category	<30	25 (39.7)
		30 - 45	13 (20.6)
		>=45	25 (39.7)

(a)

Test name	Variables		n (%)
0.45Hz Horizontal	Gender	Male	21 (70.0)
		female	9 (30.0)
	Age Category	<30	13 (43.3)
		30 - 45	7 (23.3)
		>=45	10(33.3)

(b)

Table 1: Age and sex distribution in horizontal saccades.

Test name	Variables		n (%)
0.30Hz Vertical	Gender	Male	31 (67.4)
		female	15 (32.6)
	Age Category	<30	23 (50.0)
		30 - 45	11 (23.9)
		>=45	12 (26.1)

(a)

Test name	Variables		n (%)
0.45Hz Vertical	Gender	Male	20(69.0)
		Female	9 (31.0)
	Age Category	<30	11 (37.9)
		30 - 45	7 (24.1)
		>=45	11(37.9)

(b)

Table 2: Age and sex distribution in vertical saccades.

Across all the groups, when the velocity, precision and latency of the eye movements were studied. Consistently there was no statistical difference between these values in males and females in all the directions and velocities studied (Table 3a, 3b, 4a, 4b).

However, there was a definite effect of age on all the three parameters of velocity, latency and precision, which appear to be varied across the tests and values.

In Horizontal saccades studied, the velocity of the eye tracking movements appeared to be decreasing with age. The horizontal saccades of 0.30 Hz speed eye velocity was higher in individuals below 30 years of age, which increased at 30 - 45 age and then decreased in individuals older than 45 years of age (highest being in 30 - 45 age group).

Test	Variables	Gender: Male (n = 45) Mean (SD)	Gender: Female (n = 18) Mean (SD)	Pillai's statistic	F-value	p-value
0.30Hz Horizontal	Left eye velocity	322.26 (62.03)	353.86 (62.55)	0.141	1.536	0.184
	Left eye precision	85.51 (8.47)	84.07 (8.24)			
	Left eye latency	241.50 (59.52)	253.70 (58.48)			
	Right velocity	328.67 (64.98)	345.67 (69.17)			
	Right eye precision	85.44 (7.98)	83.92 (7.81)			
	Right eye latency	234.49 (58.01)	249.67 (53.33)			

(a)

Test name	Variables	Gender: Male (n= 21) Mean (S D)	Gender: Female (n = 9) Mean (SD)	Pillai's statistic	F-value	p-value
0.45Hz Horizontal	Left eye velocity	308.87 (45.34)	325.93 (46.51)	0.356	2.123	0.09
	Left eye precision	87.78 (8.17)	82.43 (8.72)			
	Left eye latency	193.64 (52.52)	223.71 (43.79)			
	Right velocity	306.32 (41.79)	321.69 (42.11)			
	Right eye precision	87.79 (7.27)	80.49 (8.59)			
	Right eye latency	188.50 (49.88)	225.58 (49.39)			

(b)

Table 3: Comparison of Horizontal saccade parameters between Males and Females.

With aging. the precision of the eye tracking appeared to decrease. This effect was reversed in latency, as the middle age groups had the smallest latency periods. Precision of horizontal saccades was higher in early age before 30 years then reduced at 30 - 45 years of age which further decreased in individuals older than 45 years of age (highest being in individuals aged <30 years).

The Latency was more in individuals below 30 years of age then decreased at the age 30 - 45 years, which increased in individuals over 45 years of age (highest being in individuals over 45 years of age).Similar trend was observed in 0.45 Hz speed with higher values than 0.30 Hz.

In Vertical saccades of 0.30 Hz speed velocity was higher in individuals below 30 years of age, which increased at 30 - 45 age and then decreased in individuals older than 45 years of age (highest being in 30 - 45 age group). Precision of vertical saccades decreased with aging (highest being in individuals aged <30 years). Latency was more in individuals below 30 years of age then decreased at the age 30 - 45 years, which increased in individuals over 45 years of age (highest being in individuals over 45 years of age). A similar trend was observed in 0.45 Hz speed, but latency kept increasing with aging.

We used MANOVA to test the metrics for any difference among the gender (male and female) and age category ((<30, 30 - 45, > 45). Table 1b depicts no significant difference in metrics among the gender category for 0.45 Hz horizontal test since p value is greater than 0.05, which also doesn't satisfy the assumption of equality of covariance matrices (Box's M statistic = 40.355, F-value = 1.31, p-value = 0.158). Hence, we reported pillai's statistic and robust test statistic when the covariance equality assumption was violated.

Similarly, in table 2b p-value is greater than 0.05 which depicts significant statistical difference in metrics among gender category for 0.45 Hz in vertical saccades. It further satisfies the assumption of equality of covariance metrics (Box's M statistic 56.52, F-value = 1.829, p-value = 0.013). Further Table 1a and 2a shows p value greater than 0.05 which exhibits no statistically significant difference among gender category in 0.3Hz vertical and horizontal saccades. Covariance metrics for 0.3Hz horizontal and vertical respectively were found to be (Box's M statistic = 21.52, F-value = 0.878, p-value = 0.621) and matrices (Box's M statistic = 21.252, F-value = 0.829, p-value = 0.686) respectively not satisfying the assumption of equality of covariance matrices.

However, there was a significant difference in metrics among the age category (p-value = 0.03), satisfying the assumption of equality of covariance matrices (Box's M statistic = 139.38, F-value = 2.07, p-value < 0.001). Further post hock test showed significant difference among age category in left and right eye precision. Age group <30 and =>45 showed significant difference in right precision. In left eye, age group =>45 showed significant difference between the < 30 and 30 - 45.

Test	Variables	Age Category			Pillai's statistic	F-value	p-value	Post hoc
		<30 (n = 25) Mean (SD)	30 - 45 (n = 13) Mean (SD)	>=45 (n = 25) Mean (SD)				
0.3Hz Horizontal	Left eye velocity	316.42 (49.87)	347.65 (82.84)	339.44 (62.98)	0.549	3.532	<0.001	< 30 & > = 45 (p < 0.001)
	Left eye precision	90.10 (6.58)	85.77 (8.53)	79.74 (6.71)				30 - 45 & > = 45 (p-value = 0.046)
	Left eye latency	236.03 (58.44)	217.33 (41.08)	268.32 (60.60)				30 - 45 & > = 45 (p-value = 0.03)
	Right velocity	314.96 (45.63)	343.25 (77.74)	347.25 (74.69)				<30 & > = 45 (p < 0.001)
	Right eye precision	89.40 (6.95)	85.05 (8.68)	80.59 (5.90)				<30 & > = 45 (p-value = 0.018)
	Right eye latency	222.33 (55.37)	219.85 (38.90)	265.19 (57.29)				>=45 & 30 - 45 (p-value = 0.047)

(a)

Test	Variables	Age category			Pillai's statistic	F-value	p-value	Post hoc
		<30 (n = 13) Mean (SD)	30 - 45 (n = 7) Mean (SD)	>=45 (n = 10) Mean (SD)				
0.45 Horizontal	Left eye velocity	304.26 (51.85)	328.24 (52.24)	316.66 (31.44)	0.722	2.165	0.03	<30 and =>45 (p-value = 0.02) - right precision <30 and => 45 (p-value < 0.001) 30 - 45 and => 45 (p-value = 0.031) - left precision
	Left eye precision	91.02 (6.32)	86.70 (6.27)	79.50 (8.55)				
	Left eye latency	184.89 (34.55)	201.92 (58.24)	226.27 (59.48)				
	Right velocity	301.07 (43.31)	330.27 (55.77)	310.21 (24.84)				
	Right eye precision	90.75 (5.43)	86.65 (5.93)	78.16 (7.39)				
	Right eye latency	117.80 (31.64)	199.94 (50.78)	227.76 (63.55)				

Table 5: Comparison of Different Age groups in Horizontal saccades.

Test	Variables	Age Category			Pillai's statistic	F-value	p-value	Post hoc
		<30 (n = 23) Mean (SD)	30 - 45 (n = 11) Mean (SD)	> = 45 (n = 12) Mean (SD)				
0.3Hz Vertical	Left eye velocity	248.45 (44.24)	286.82 (28.34)	266.45 (48.16)	0.783	4.184	<0.001	30 - 45 & > = 45 (p-value = 0.001)
	Left eye precision	85.70 (10.98)	81.84 (11.48)	80.11 (13.98)				30 - 45 & < 30 (p-value = 0.044)
	Left eye latency	237.49 (47.67)	202.25 (28.22)	276.06 (52.97)				30 - 45 and > = 45 (p-value = 0.024)
	Right velocity	254.54 (44.73)	290.48 (33.10)	245.71 (28.30)				< 30 and > = 45 (p-value = 0.004)
	Right eye precision	89.41 (10.15)	83.36 (11.20)	76.81 (9.82)				< 30 and > = 45 (p-value = 0.012)
	Right eye latency	228.35 (48.43)	198.59 (27.85)	279.38 (56.54)				> = 45 and 30 - 45 (p-value < 0.001)

(a)

Test	Variables	Age Category			Pillai's statistic	F-value	p- value
		<30 (n = 11) Mean (SD)	30 – 45 (n = 7) Mean (SD)	>=45 (n = 11) Mean (SD)			
0.45Hz Vertical	Left eye velocity	236.21 (23.50)	277.90 (27.54)	258.54 (40.12)	0.681	1.892	0.062
	Left eye precision	88.32 (11.57)	81.70 (11.90)	73.89 (4.46)			
	Left eye latency	197.72 (39.41)	201.13 (23.48)	246.58 (58.17)			
	Right velocity	240.40 (30.43)	272.11 (28.20)	266.03 (42.43)			
	Right eye precision	88.46 (12.17)	82.37 (15.20)	75.47 (6.59)			
	Right eye latency	197.23 (35.92)	205.25 (25.41)	240.67 (58.22)			

(b)

Table 6: Comparison of Different Age groups in Vertical saccades.

Discussion

Saccades are fast eye movements aiming at bringing visual target of interest onto the fovea. Saccades start suddenly (latency of 200mmsec) and have a high initial acceleration. The time required for information regarding the target of interest to travel to the brainstem must be less than the Latency. Brainstem or cerebellum lesions are the common cause of all clinically important saccadic disorders [1].

Peak velocity and latency are developed through childhood and preadolescence, which gets stabilized in the middle decades and declines in later decades [4].

S. Wilson., *et al.* found no significant differences between saccadic parameters of males and females [5]. D. Mazumdar., *et al.* also found no significant difference between saccadic parameters of males and females [11].

In our study too there was no statistical difference in values between males and females suggesting that physiological parameters such as speed of neuronal transmission and consequent values of latency, velocity etc. are not altered.

Any changes in oculomotor measurements are usually connected with the changes in the function of brain area and pathway. Aging has been associated with various central nervous system changes, such as dendrite loss, neuron loss, reduced branching, reduced cerebral perfusion, damaged cerebral metabolism and altered transmitter metabolism. Compensating age-related impairments are reduced due to these changes in sensory inputs. Slowing down of information processing and reduced nerve conduction velocity explains the age-related differences encountered in eye movement recordings [10].

Additionally, there is a selective wide-spread deterioration of both white and gray matter in the cerebral cortex [1]. There is increase in mean latency which accompanies aging is the result of degeneration of neurons of the eye-movement areas of cerebral cortex [1].

Fokion., *et al.* found that saccade latency increased with age while saccade velocity and accuracy declined with age. Their statistical analysis revealed remarkable difference between their study groups for all the saccadic parameters. In literature, several studies have reported varying results with electro-oculography techniques [1]. Wilson., *et al.* reported positive correlation between saccadic latency and age [5]. Abel., *et al*. reported zero effect of age on saccade velocity [1]. However, Wilson., et al. reported that even though effect of age is weak, effect is higher for large saccades (>350) [5].

Elizabeth L. Irving., *et al.* found a significant correlation between saccade size and age which further warrants investigation [4]. Their results were in accordance with the studies who have found decrease in precision with age [6,9]. These types of studies have evaluation of precision as a function of saccade size and age and use of large saccades as common factor. Studies which do not show any effect of age have used very small saccade sizes and tested over age ranges (4 - 38 years) which would not show any significant effect of age [4].

Fokion., *et al.* found a statistically significant difference for all three evaluated parameters in between groups (p < 0.001), with a significant linear trend for increasing latency and decreasing velocity and accuracy with increasing age (p trend < 0.001) [1].

Fioravanti., *et al.* reported fastest saccades in the youngest group they tested [7], whereas Elizabeth L. Irving., *et al.* found saccades to be very slow in younger children than in older children and adults [4]. They also found longest durations in youngest group and asymmetry ratios to be highest [4]. Generally, one would interpret if saccades for a specific size is faster then, they would be shorter with minimum asymmetry ratios. Consequently, Funk and Anderson deduced that saccades of children's were faster than adults since durations were shorter in children compared to adults in the literature [8]. Fioravanti., *et al.* used infrared limbal tracker and had to apply linearization curves to their data, establishing chances of systematic errors. It is uncertain as to whether the curves were produced for individual or for each age groups, or whether same curves were utilized for every individual [7].

The present study observed an effect of age on all saccadic parameters studied as already described. Elderly healthy individuals showed a declined performance in all the parameters tested. We postulate that this finding and the literature above argue for caution in attributing any absolute values to determine hyper or hypo function, and for the need for using comparative values between the affected and contralateral side in assessing function in patients of any neurovestibular disorder.

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