

Normal Values of Standard Full Field Electrophoretinography in an Iranian Population

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Purpose: To determine normal values of standard full-field electrophoretinography (ERG) and to evaluate their variations with age in an Iranian population.

Methods: Through convenient sampling, 170 normal subjects 1-80 years of age were selected from residents of Tehran. ERG amplitudes and implicit time values were measured according to recommendations by the International Society for Clinical Electrophysiology of Vision. Evaluations consisted of light-adapted ERG including single-white flash and 30-Hz flicker response; and dark-adapted ERG including rod, maximal dark-adapted and cone responses.

Results: No significant difference in ERG values was observed between men and women, or between right and left eyes. ERG amplitudes were lower ($P=0.04$) and implicit time values were greater ($P=0.03$) in subjects 70-80 years of age as compared to younger individuals.

Conclusions: ERG parameters are significantly diminished with age. Our results may serve as a reference against which standard ERG responses can be compared.

Key words: Electrophoretinography; Iran

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INTRODUCTION

Full field electrophoretinography (ERG) is a well established diagnostic procedure employed in the evaluation of retinal disorders. It determines the functional integrity of the retina, including rods and cones in the outer retina as well as associated pathways in the middle and inner layers of the retina.¹⁻³ A standard ERG includes five recordings; response to dim stimulation in dark adaptation (scotopic rod response), response to a bright stimulus in dark adaptation (scotopic combined rod-cone response), oscillatory potentials, response to a bright stimulus in light adaptation (photopic

single-flash cone response), and response to a flickering stimulus in light adaptation (photopic 30-Hz flicker cone response). Significant changes in the amplitude or implicit time of each response may indicate a distinct retinal disorder.¹⁻⁴

Since 1989, the International Society for Clinical Electrophysiology of Vision (ISCEV) and the National Retinitis Pigmentosa Foundation (NRPF) have attempted to standardize ERG procedures.⁴⁻⁶ The methodology is updated on a regular basis in order to standardize ERG responses and make them universally comparable. This standard provides simple recommendations on technical procedures to

record reproducible ERGs under defined conditions in patients of all ages.⁶ However, despite unifying the practice, normal ERG responses may be influenced by other factors such as race, age, sex, medications, media clarity and refraction.⁶⁻¹²

The ISCEV recommends that each laboratory establish normal values based on its own equipment and patients.⁶ In this study, we measured ERG responses based on ISCEV standards in ophthalmologically normal Iranian subjects of different ages while attempting to eliminate avoidable confounding factors by using strict inclusion criteria.

METHODS

One hundred seventy Iranian residents of Tehran aged 1 to 80 years were enrolled for the purpose of the study. We used convenient sampling and selected the study subjects among hospital personnel, clients seeking spectacle prescriptions and patients' attendants. The study subjects were asymptomatic with normal best-corrected visual acuity, normal color vision, normal eye examination, clear media, and low or insignificant refractive errors (myopia less than -6.00 diopters). In preverbal children, fixation behavior, preferential looking and Allen chart were used instead of Snellen visual acuity measurement. In order to avoid the influence of lenticular nuclear sclerosis, only patients with apparently clear lens on dilated biomicroscopy were included. Individuals with optic nerve disease, neurological impairment, systemic diseases, or a family history of heritable retinal disorders were excluded. No subject was on long-term medications. All ERG measurements were performed at the Visual Electrophysiology Unit of Rasoul-Akram Hospital. The Institutional Review Board of the hospital approved the study and informed consent was obtained from study subjects.

Recording procedures adhered to a recommended international standard for clinical electrophysiological measurements.⁶ Pupils were fully dilated using 1% tropicamide and 2.5% phenylephrine eye drops. Silver/nylon fiber

electrodes (DTL, Laird Technologies, Sauquoit Inc. Scranton, USA) were used. The active electrode was placed over the middle third of the lower eyelid of each eye. ERG recording in children was performed following oral intake of chloral hydrate for sedation. ERG recordings were obtained on both eyes. The ISCEV-ERG GF program which is an integrated part of the system (Roland Consult, Electrophysiologic Diagnostic Systems, Wiesbaden, Germany) was used to record standard ERGs. Stimulation was performed using a full field flash Ganzfeld stimulator (Roland Consult). All responses were differentially amplified, displayed on an oscilloscope, digitized and stored on a compact disc. An adjustable voltage window was used to reject records contaminated by artifacts. Dark adapted ERG responses were obtained after a minimum of 30 minutes of dark adaptation and included an isolated rod, standard flash (maximal) response, and oscillatory potentials. Light adapted responses included a single white flash and 30-Hz flicker.

For each of the five stimuli, right and left eyes were individually tested and their data was processed separately. Thereafter, responses of both eyes for each stimulus were averaged to determine the individual subject's data. The subjects were divided into 8 age strata with 10-year intervals; within each age group, the median and range were calculated for each parameter. Average amplitudes and implicit times were analyzed using *t*-test and ANOVA.

RESULTS

Implicit times and amplitudes of ERG are stratified by gender and age groups in Tables 1 to 4. No significant difference was found between right and left eye measurements by gender and age. There was also no significant difference between male and female ERG amplitudes and implicit times within different age groups. However, amplitude values were significantly decreased and implicit time was significantly increased in both genders in the 70-80 year age group as compared to other age groups ($P=0.04$ and $P=0.03$ respectively).

Table 1 Median and 95% confidence interval for ERG amplitude (microvolt) in male subjects

Age (yr)	1-10		11-20		21-30		31-40		41-50		51-60		61-70		71-80	
Eye	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
a-wave rod response	72	69	74	75	73	71	76	74	72	74	77	72	73	71	65	66
b-wave rod response	159	157	168	167	166	164	135	132	128	131	145	142	143	144	125	128
a-wave max response	231	228	226	221	225	228	195	192	198	201	187	192	191	189	173	174
b-wave max response	380	382	390	385	405	402	390	398	408	410	412	415	398	402	375	378
OP ₂	37	35	38	41	42	39	34	32	33	34	34	32	33	35	32	30
N ₁ -P ₁	85	87	92	89	95	92	89	91	84	83	94	96	89	92	81	79
30-Hz flicker	52-105	48-150	51-148	55-161	45-165	47-138	49-161	48-159	52-158	58-135	49-145	51-110	48-115	47-125	42-138	45-145
a-wave cone response	37	38	36	35	38	37	34	34	33	34	30	31	31	31	29	30
b-wave cone response	157	160	161	162	148	149	158	157	156	155	161	162	153	152	140	138
	88-240	87-225	89-285	81-245	89-251	95-245	85-225	87-231	91-245	92-251	87-215	89-225	75-215	71-210	55-195	58-192

ERG, electroretinogram; Max, maximum; OP, oscillatory potential; N₁-P₁, interval between first negative and positive waves.**Table 2** Median and 95% confidence interval for ERG amplitude (microvolt) in female subjects

Age (yr)	1-10		11-20		21-30		31-40		41-50		51-60		61-70		71-80	
Eye	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
a-wave rod response	70	71	72	74	70	73	75	73	71	73	71	72	74	73	67	65
b-wave rod response	157	159	166	168	165	163	141	144	132	134	141	138	141	143	127	125
a-wave max response	234	229	222	226	229	224	199	201	201	203	191	189	189	192	175	171
b-wave max response	375	380	392	387	407	401	395	397	407	409	415	410	395	399	374	387
OP ₂	36	37	39	39	42	41	35	32	32	33	33	34	31	33	34	32
N ₁ -P ₁	87	86	94	91	93	90	88	91	83	84	93	98	90	91	83	79
30-Hz flicker	52-110	48-158	48-165	47-159	51-165	46-162	48-148	51-161	55-149	48-158	47-161	48-175	51-158	52-161	41-148	45-145
a-wave cone response	36	38	37	36	36	35	33	34	34	33	29	30	31	31	28	31
b-wave cone response	156	159	162	161	149	151	156	158	157	158	160	162	155	151	138	139
	85-245	84-239	84-262	85-252	79-251	86-245	87-235	85-241	251-79	89-242	91-258	85-245	87-235	78-215	58-198	56-197

ERG, electroretinogram; Max, maximum; OP, oscillatory potential; N₁-P₁, interval between first negative and positive waves.**Table 3** Median and 95% confidence interval for ERG implicit time (milliseconds) in male subjects

Age (yr)	1-10		11-20		21-30		31-40		41-50		51-60		61-70		71-80	
Eye	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
a-wave rod response	39	40	43	42	38	37	42	44	43	42	41	44	42	41	46	47
b-wave rod response	86	88	79	81	83	82	88	86	92	95	88	96	89	92	99	99
a-wave max response	19	20	16	18	20	21	22	21	24	23	22	21	24	23	25	25
b-wave max response	41	43	39	41	42	41	45	42	44	43	42	43	44	42	48	49
OP N ₂	13	14	14	15	14	13	15	14	16	15	15	15	16	15	17	18
OP P ₂	31	30	29	31	28	30	29	30	31	32	30	29	30	31	32	32
a-wave cone response	15	14	14	15	15	16	15	16	15	14	15	15	15	16	16	17
b-wave cone response	30	31	31	30	32	31	32	31	30	31	31	31	31	28	32	32
30-Hz N ₁	12-15	12-16	12-16	11-15	12-14	12-15	12-15	12-16	13-16	12-16	12-16	13-16	13-16	13-16	13-17	13-17
30-Hz P ₁	26	26	26	26	27	25	26	26	27	27	26	27	26	30	27	28
	23-28	23-29	25-29	24-29	24-31	23-29	23-30	24-29	24-31	25-31	24-29	25-31	24-29	24-36	25-32	25-32

ERG, electroretinogram; Max, maximum; N₁, first negative wave; P₁, first positive wave; OP N₂, oscillatory potential-second negative wave; OP P₂, oscillatory potential-second positive wave.

Table 4 Median and 95% confidence interval for ERG implicit time (milliseconds) in female subjects

Age (yr)	1-10		11-20		21-30		31-40		41-50		51-60		61-70		71-80	
Eye	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
a-wave rod response	40 30-65	39 28-64	42 28-62	42 28-65	21 15-24	21 16-25	21 15-26	20 14-25	44 28-64	43 29-71	41 28-69	43 28-66	42 31-65	41 31-62	47 30-69	46 31-72
b-wave rod response	86 68-97	87 67-105	80 71-98	79 69-97	83 72-103	83 71-99	87 69-97	86 70-99	92 72-103	95 67-98	97 72-106	97 71-99	97 72-99	90 78-105	91 75-106	98 76-108
a-wave max response	20 15-24	20 16-26	17 14-20	18 14-22	21 16-25	21 15-26	20 14-25	23 16-25	24 14-27	24 14-27	21 17-24	21 15-25	24 14-26	24 16-26	25 19-29	25 20-28
b-wave max response	42 32-46	43 25-47	39 34-45	41 33-45	41 34-48	42 33-49	45 32-48	43 34-51	44 35-51	44 34-50	43 36-48	42 33-49	43 34-51	43 35-53	48 37-55	48 36-54
OP N ₂	14 12-17	14 12-16	13 12-16	14 12-17	15 13-18	14 12-16	14 12-16	15 14-17	13 12-15	15 13-18	16 13-17	15 14-16	16 13-17	15 13-16	16 15-19	18 15-20
OP P ₂	30 8-33	30 28-32	29 28-32	31 27-33	29 28-32	30 29-31	29 28-31	29 28-33	31 28-32	31 28-33	31 29-33	32 09-33	30 29-32	29 28-32	32 29-34	32 30-34
a-wave cone response	14 13-17	14 12-16	14 13-18	15 14-17	15 14-16	14 13-17	15 13-18	15 14-18	16 14-18	15 13-18	14 13-16	14 13-17	14 13-16	15 13-18	17 14-19	17 14-18
b-wave cone response	30 28-31	30 24-33	30 28-33	31 28-33	31 29-33	32 29-34	32 29-33	31 29-32	31 28-32	30 28-32	31 29-33	30 29-33	32 30-34	31 29-33	33 30-34	32 30-33
30-Hz N ₁	14 12-17	14 12-16	13 12-16	13 11-15	13 12-14	13 12-15	14 12-15	13 12-15	14 13-15	14 12-16	13 12-16	13 12-16	14 12-15	13 13-17	15 13-17	15 12-17
30-Hz P ₁	25 23-28	25 23-29	26 24-29	26 24-28	29 27-32	26 23-28	25 24-30	26 25-29	26 25-31	27 24-30	26 24-29	26 24-29	27 24-30	26 25-30	28 25-32	27 25-32

ERG, electroretinogram; Max, maximum; N₁, first negative wave; P₁, first positive wave; OP N₂, oscillatory potential-second negative wave; OP P₂, oscillatory potential-second positive wave.

DISCUSSION

This study provides normal ranges for ERG responses in different age groups in an Iranian population. All procedures were performed as recommended by the International Standardization Committee.⁶ Our study size (170 individuals) was much larger than certain studies reporting normal ERG values.¹³ ERG measurements obtained herein show a difference of 5-15% in amplitude and 15-20% in implicit time in comparison to ISCEV reported normal values.¹³ Since we eliminated confounding factors affecting ERG amplitude and implicit time such as refractive errors, intraocular pressure, media clarity, systemic medications and retinal diseases,⁶⁻¹¹ the ethnicity of studied subjects may account for the observed difference.

We paid particular attention to age as a variable reported to be associated with a decrease in full-field ERG responses.^{11,12} The reason for decrease in ERG amplitude in the elderly is not well understood. Although our study subjects were clinically normal, sub-clinical pathologic conditions cannot be ruled out. Factors such as subtle preretinal media changes or reduction in photopigment optical density¹¹, and bipolar or Muller cell death in the ageing retina could be the reason for the decline in amplitude with increasing age.¹⁴

A statistically significant effect of gender on ERG recordings has been reported^{8,11} but, we did not observe any difference between male and female subjects in our study. Many technical factors such as electrode placement, integrity of the ocular surface and pupil size may affect interocular difference in ERG amplitudes, however, in our series no significant difference was found between right and left eyes. Our results support the findings of Rotenstreich et al¹⁵ who found small interocular differences in ERG b-wave amplitudes for five different stimulus responses.

Specific amplitude and implicit time values for ERG will probably differ among different laboratories due to minor variations in recording electrodes, equipment and protocol.⁶ Nevertheless, the present data were obtained under rigidly controlled conditions and can be used as a basis for comparison in our country.

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