Original Article

Evaluation of Agreement Between Sweep Visual Evoked Potential Testing and Subjective Visual Acuity

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Abstract

Objectives: The primary objective of this study was to evaluate the agreement of visual acuity (VA) obtained with the sweep visual evoked potential (sVEP) method with the VA obtained with the Snellen chart. The secondary objective was to examine the effect of age and gender on agreement.

Materials and Methods: Best corrected VAs of subjects were recorded with the Snellen chart, and sVEP testing was performed according to the recommendations of the International Society for Clinical Electrophysiology of Vision (ISCEV). Snellen VAs and sVEP measurements were analyzed using logMAR conversion for statistical analysis. Agreement was evaluated with Bland-Altman analysis.

Results: The study included 49 subjects with a mean age of 53.5±17.3 years (range: 19-75 years) and mean Snellen VA of 0.31±0.32 logMAR (range: 1.3-0.0 logMAR). In the Bland-Altman analysis, the mean differences between the VA and sVEP measurements (VA-sVEP) were significantly different and outside the limits of agreement (p=0.035). A significant proportional bias (p=0.0007) was found in the regression analysis performed between VA-sVEP and the mean VA. According to the Bland-Altman analysis of sex subgroups, there was a significant difference between VA and sVEP measurements in female subjects (p=0.006). The difference between VA and sVEP measurement increased significantly with older age (R^2: 0.306, p<0.001, β: 0.05 [0.03, 0.08]).

Conclusion: In conclusion, sVEP measurements and VAs did not show statistical agreement. Cranial anatomy and endocrine differences of the subjects may affect their sVEP measurements. The difference between the methods varies according to VA level. Directly using sVEP results instead of VA would not be appropriate.

Keywords: Visual evoked potentials, spatial frequency limits, Snellen, sweep VEP, pattern VEP

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Introduction

Visual acuity (VA) is the most commonly measured visual function and an important part of routine ophthalmology practice. Psychophysical VA is an important clinical assessment, typically measured using subjective tests such as naming, pointing, or matching letters or symbols on calibrated charts. However, an electrophysiological evaluation may be required for assessment in non-cooperative individuals (pediatric age group, individuals with intellectual disability, simulating or converting individuals).[1,2,3,4]

Sweep visual evoked potential (sVEP) is a type of VEP testing used for the evaluation of visual function. In the sVEP method, the stimulator generates a pattern stimulus that alternates at a high temporal frequency and produces a visual evoked response. To measure VA, the size of the pattern is rapidly reduced and the smallest pattern that produces a response is detected, and VA is determined by regression analysis.[5,6]

Some studies evaluating the agreement and relationship between sVEP measurements and psychophysical VA demonstrated a statistically significant difference between the two methods, while other studies found the two methods to be similar.[7,8,9,10] Disagreement between the two methods may be explained by the fact that VEPs arise from the fovea and perifovea and the test is dynamic, whereas psychophysical VA requires a small number of cones and is a static test.[11,12,13] Despite this, sVEP measurement may be the only safe method available for VA evaluation when the psychophysical method is not possible. In this study, our primary objective was to evaluate the agreement between VA measured by sVEP and psychophysical VA obtained with the Snellen chart. Our secondary objective was to examine the effect of age and sex on agreement.

Materials and Methods

All procedures performed in studies involving human participants followed the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol was approved by the Erciyes University Local Ethics Committee (decision no: 2020/622, date: 16.12.2020). Informed consent was obtained from all individual participants included in the study.

Best corrected VAs of the subjects were recorded using the Snellen chart at a distance of six meters (ACP-700 auto chart projector, Unicos Co., Korea). Routine anterior and posterior segment examinations were performed for all subjects.

Forty-nine subjects with different vision levels (between 0.05 and 1.0 decimal) according to the Snellen chart were included in the study. Data from both eyes of each patient were recorded. One eye was analyzed for each participant by random selection using the www.randomizer.org website.

Sweep VEP (Metrovision HVM-MonPackOne, France) recordings were performed according to the recommendations of the International Society for Clinical Electrophysiology of Vision (ISCEV) for the VEP spatial frequency limit.[1,14] In order to measure VA, the size of the pattern was reduced rapidly. Twenty different pattern sizes (1.5-30 cycles per degree [cpd]) were presented in succession, within 11 seconds for each sweep. Recording parameters were as follows: stimulation frequency 12 Hz, analysis window 1.3 s, and checkerboard stimulus. Ganzfeld background mean luminance was approximately 50 cd/m^2 and spatial resolution was 1024 x 768. A discrete Fourier transform was performed on the recorded signals. While recording, the subjects were asked to look at the red fixation point in the middle of the screen. The active electrode was placed on the occipital midline (Oz), the reference electrode was placed on the frontal midline (Fz), and the neutral electrode was placed on the forehead. The fellow eye was covered with an eye patch. The necessary refraction correction was applied and the pupil was not dilated. The device software automatically determined VA as the smallest pattern size that produced a response.

Statistical Analysis

Psychophysical VAs and sVEP measurements were converted from decimal to logMAR for statistical analysis. All VA results in the text, tables, and graphs are presented in logMAR. Statistical analysis was performed using MedCalc version 20 and SPSS version 22. Descriptive statistics were calculated and agreement between psychophysical VAs and sVEP measurements was evaluated with Bland-Altman analysis. According to distribution normality, parametric (paired-samples t, independent-samples t) and non-parametric (Wilcoxon signed-rank, Mann-Whitney U) tests and Pearson or Spearman correlation analysis were performed. Linear regression analysis was performed between age and the difference between psychophysical VA and sVEP measurement.

Results

The subjects ranged in age from 19 to 75 years (53.5±17.3 years); 14 (28.6%) were male and 35 (71.4%) were female. The patients were heterogeneous in terms of visual impairments and etiologies (e.g., age-related macular degeneration, diabetic retinopathy, macular hole, glaucoma). Subgroup analysis was not performed because the number of patients was not sufficient. The mean best-corrected psychophysical VA was 0.31±0.32 logMAR (range: 1.3-0.0 logMAR). The mean sVEP measurement was 0.26±0.28 (range: 1.3-0.05 logMAR). There was a significant difference between the overall mean psychophysical logMAR VA and sVEP measurements (p=0.030). However, a strong correlation was found between individuals' psychophysical logMAR VA and sVEP measurements (r=0.815, p<0.001). Psychophysical logMAR VA and sVEP measurements were also compared within the sex subgroups. The results are presented in Table 1.

There was no significant difference in the ratios of right and left eyes between the male and female subgroups. There was also no significant difference in psychophysical logMAR VA between the male and female subgroups, although women had significantly higher sVEP measurements than men. Comparisons between the male and female subgroups are presented in Table 2.

In the Bland-Altman analysis, the mean differences between the psychophysical logMAR VA and sVEP measurements (VA-sVEP) were significantly different and outside the limits of agreement (p=0.035). There was a significant proportional bias (p=0.0007) in the regression analysis performed between the VA-sVEP and the mean psychophysical VA (logMAR). No fixed bias was found. The regression equation was sVEP= 0.24 [0.10, 0.38] Snellen - 0.02 [-0.08, 0.03]. There was a significant proportional bias in the female subgroup (p=0.0015). The Bland-Altman plots and table are presented in Figure 1

Table 1. Comparison of psychophysical visual acuity and sVEP measurements

	Psychophysical visual acuity	sVEP measurement	p
Entire group with random eye selection	0.31±0.32	0.26±0.38	0.030*
Male	0.41±0.37	0.40±0.31	0.767
Female	0.28±0.30	0.20±0.25	0.003*

Values are expressed as logMAR, mean ± standard deviation. *Statistically significant p value (<0.05, Wilcoxon test), sVEP: Sweep visual evoked potentials

Table 2. Comparison of psychophysical visual acuity and sVEP measurements by sex

Variables	Male	Female	p
Eye (right/left)	6/8	23/12	0.141
Psychophysical VA	0.41±0.37	0.28±0.30	0.200
sVEP measurement	0.40±0.31	0.20±0.25	0.028*

Values are expressed as logMAR, mean ± standard deviation. *Statistically significant p value (<0.05, Pearson chi-square and Mann-Whitney U tests), VA: Visual acuity, sVEP: Sweep visual evoked potentials

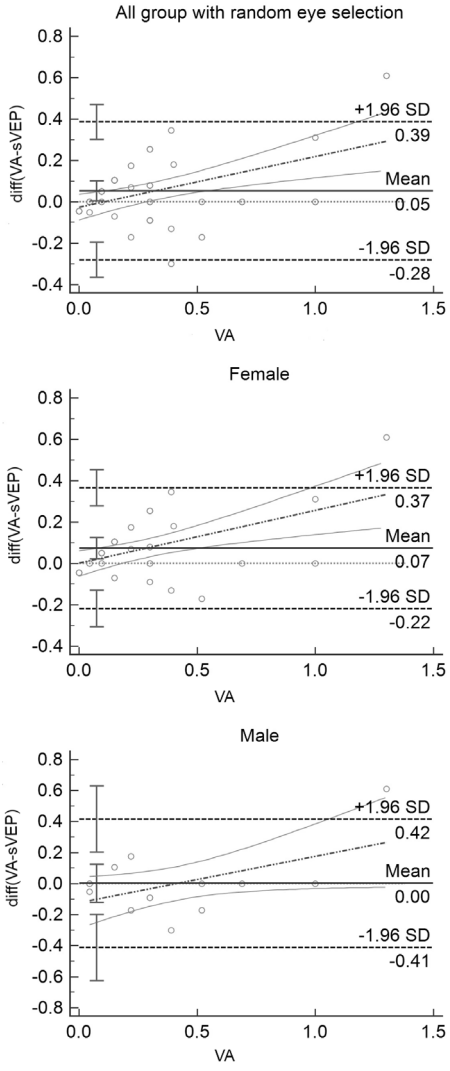

Figure 1. Bland-Altman plots of agreement between psychophysical (Snellen) visual acuity (VA) and sweep visual evoked potential (sVEP) values. Data were converted to logMAR values for the plots. There was a proportional bias for all subjects and female subjects. There was agreement between methods for male subjects

and Table 3. A correlation was found between age and VA-sVEP according to regression analysis (R^2: 0.306, p<0.001, β: 0.05 [0.03, 0.08]) and is presented in Figure 2.

Discussion

Our study showed that the psychophysical VAs (logMAR) and sVEP measurements (logMAR) were not statistically in agreement. The difference between the methods (VA-sVEP) varied according to level of visual acuity. At low vision levels, sVEP measurements were higher than psychophysical logMAR VA. We also found that VA-sVEP was moderately correlated with age. Finally, we found that the two methods showed poor agreement in female subjects.

The agreement between psychophysical VA and sVEP measurement depends on many factors, including the type of visual impairment (e.g., corneal, retinal, and optic nerve pathologies, cataract), non-identical optotypes (e.g., E chart, Landot C chart, and Snellen chart), non-identical stimuli (e.g., checkerboards and sinusoidal), the use of different techniques used to separate signal from noise, age, and other individual and technical factors.[4,7] In studies conducted with etiologically heterogeneous groups, it has been shown that sVEP measurement exceeds the psychophysical VA at low vision levels, which is consistent with our study.[4] In a study that evaluated psychophysical VA using different stimuli, it was stated that psychophysical VA was better than sVEP measurement, but contrary to our study, there was agreement between the methods in subjects with low vision and disagreement in subjects with high vision.[15] In a study evaluating the repeatability of psychophysical VA and sVEP measurement between visits and sessions, the intraclass correlation coefficient was 0.88 for psychophysical VA and 0.71 for sVEP, indicating that sVEP has slightly worse repeatability than psychophysical VA.[16] These results show that agreement between methods depends on the type of visual impairment, as well as temporal and methodological factors.

In our study, we found a correlation between age and VA-sVEP. sVEP measurements were lower than psychophysical VA before age 40 but higher after age 40. We could explain this situation by clustering people with low level of VA aged 40 years and older in our study group (Figure 2). When the literature is

Table 3. Analysis of agreement between psychophysical visual acuity and sVEP visual acuity

Variables		VA-sVEP [95% CI]	p (H_0: mean=0)	Lower limit [95% CI]	Upper limit [95% CI]
Entire group with random eye seleciton		0.052 [0.003, 0.100]	0.035*	-0.280 [-0.364, -0.196]	0.385 [0.301, 0.469]
	Reg. equation	sVEP = -0.025 [-0.086, 0.036] + **0.244 [0.108, 0.380]** Snellen			
Male		0.001 [-0.120, 0.123]	0.981	-0.412 [-0.626, -0.199]	0.415 [0.201, 0.629
Female		0.072 [0.021, 0.124]	0.006*	-0.219 [-0.307, -0.130]	0.365 [0.276, 0.453]
	Reg. equation	sVEP = -0.001 [-0.060, 0.062] + **0.255 [0.104, 0.406]** Snellen			

Values are expressed as logMAR. *Statistically significant p value (<0.05 Bland Altman test results), statistically significant confidence intervals (p value <0.05) shown in bold; VA, sVEP: Difference between psychophysical visual acuity and sweep visual evoked potential measurements, CI: Confidence interval; Reg.: Regression

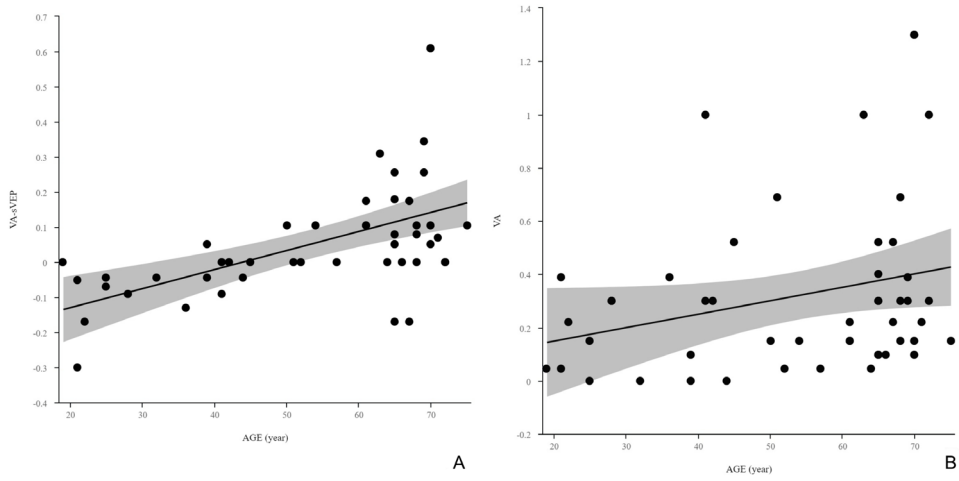

Figure 2. Scatter plots between age and the difference between Snellen visual acuity (VA) and sweep visual evoked potential (sVEP) values (VA-sVEP) (A) and VA (B). The difference between the two methods increased with age and was located outside the confidence interval in graph A. Subjects with low VA were more clustered in the older age group in graph B

reviewed, the opposite is expected, as age-related reduction in spatial frequency and reduced retinal illumination due to senile miosis are expected.[17,18] In the sex-based analysis, we found that sVEP measurement was higher than psychophysical VA in female subjects. This may be due to endocrine differences, and there are studies in the literature showing that female patients have higher VEP amplitudes and shorter implicit time.[19,20,21] When VEP parameters were evaluated in pregnant and non-pregnant women, a shortening of implicit time was observed in pregnant women. This difference was attributed to differences in circulating sex steroids, and it was suggested that this effect may be the main reason for the difference between the sexes.[22] Sex-related variations in the anatomical cranial structure may be another reason.[23,24]

A VEP is electrophysiological signals derived from electroencephalographic (EEG) activity and recorded from the visual cortex in the occipital region. Skull thickness has been reported as one of the factors affecting EEG responses.[25] The size, location, and spatial arrangement of human brain networks can vary between subjects.[26] The visual cortex can also show individual variations. Furthermore, it has been shown that VEP amplitude is higher and latency is shorter in dominant eyes compared to nondominant eyes.[27,28] Another factor to consider is binocular rivalry.[29] It has been suggested that rivalry underlies amplitude fluctuations in monocularly recorded VEP.[30,31] It has been reported that both eyes are not synchronized and there are fluctuations in VEP responses.[32] Psychophysical VA test also assesses cognitive function. However, sVEP assesses cellular electrical activity, not cognitive functions. In addition, sVEP is a dynamic test, there is no fixed target like Snellen, so it is more visible to the patient.[13] These may differ between subjects and may ultimately be the cause of differences between the two methods.

Study Limitations

Our study may have some limitations. The average age of the participants was relatively high, so our results may not provide information about the agreement between measurements in younger patients. Another limitation was the inability to include subjects in all age ranges and at every visual level for both sexes. Information on the etiology of low vision of the patients was not presented and could not be analyzed. Our last limitation is that we converted decimal VA to logMAR VA; we could not directly measure logMAR VA.

Conclusion

In conclusion, sVEP measurement and psychophysical VA did not have statistical agreement. When subjects were evaluated according to gender, psychophysical VA and sVEP measurements were not statistically congruent for female subjects. Individual cranial anatomy and endocrine-chemical differences may affect sVEP results. The difference between measurements varies according to the VA level. It would not be correct to use sVEP results directly instead of VA. It would be appropriate to detect the bias between sweep VEP and psychophysical VA and to correct the measurement values in clinical practice.

Ethics

Ethics Committee Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the Erciyes University Local Ethics Committee (approval no: 2020/622, date: 16.12.2020) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Authorship Contributions

Concept: O.A.P., Z.Ç., H.A., Design: O.A.P., Z.Ç., H.A., Data Collection or Processing: O.A.P., H.Ş., Z.Ç., Analysis or Interpretation: O.A.P., H.Ş., Z.Ç., H.A., Literature Search: O.A.P., H.Ş., Writing: O.A.P., H.Ş.

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

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