The Thai Logarithmic Visual Acuity Chart

PAISAN RUAMVIBOONSUK, M.D.*,
MONTIP TIENSUWAN, Ph.D.**

Abstract

Objective : To evaluate visual acuity scores from the Thai and the standard logarithmic visual acuity chart.

Design : Comparative non-randomized clinical study.

Participants and Method : 153 subjects, calculated from sample size estimation, without any ocular disease and aged between 18 and 80 years old who could read English and at least 3 out of 5 letters of the largest line of both charts were enrolled to use only their right eyes to read the Thai and the standard logarithmic visual acuity chart without any refractive correction. 27 subjects came back for second measurements of visual acuity in the same manner as the first a week later.

Main Outcome Measurement : The visual acuity scores were divided into the Snellen or the whole line score and the ETDRS or the letter-by-letter score. The former was compared by weighted Kappa and the latter was compared by the paired *t*-test.

Results : There was high agreement in weighted Kappa between the Snellen scores from the Thai and standard chart (k = 0.7375). There was also high agreement in weighted Kappa between the Snellen scores from the first and second reading of the Thai chart (k = 0.7304) and the standard chart (k = 0.7282). A high correlation was observed between the ETDRS scores from the Thai and standard charts (r = 0.947). Also there was a high correlation between the ETDRS scores of the first and second reading of both the Thai chart (r = 0.962) and the standard chart (r = 0.952). There was a significant difference between the ETDRS scores from the Thai and standard chart ($p<0.0001$). There was no significant difference between the ETDRS scores from the first and second reading of either the Thai chart (p=0.794) or the standard chart (p=0.62).

Conclusion : The Snellen visual acuity score from the Thai chart is comparable to the standard chart. Although the ETDRS score from the Thai chart is different statistically from the standard chart, its test-retest variability tends to be low. This suggests the possibility of using the Thai chart for monitoring of the ETDRS score in research studies.

Key word : Visual Acuity Score, Logarithmic Visual Acuity Chart, Thai

RUAMVIBOONSUK P & TIENSUWAN M
J Med Assoc Thai 2002; 85: 673-681

* Department of Ophthalmology, Rajavithi Hospital,
** Department of Mathematics, Faculty of Science, Mahidol University, Bangkok 10400, Thailand.

Visual acuity is the single most important indicator of visual function. The tool for measuring visual acuity is a visual acuity chart. A widely used visual acuity chart is Snellen's chart, which was originally invented in 1862(1).

There are several limitations in the Snellen visual acuity chart. The increment of size of optotypes in each line and the line above is not in proportion. The numbers of optotypes in each line of the chart are different. The 7 levels of scoring are considered too coarse. In 1976, a new visual acuity chart was constructed to overcome such limitations (2). The increment of size of optotypes from each line to the line above in this new chart is in proportion on a logarithmic scale, which was recommended for adoption as a standard for visual acuity measurements(3). The numbers of optotypes in each line are equal. There are 5 optotypes each. These optotypes are arranged so that each line has approximately the same difficulty score(4). The chart has 14 levels of scoring and it has been called the logarithmic visual acuity chart. Such a chart is used for outcome measurements in standard research in ophthalmology(4), especially in extensive studies such as the "Early Treatment Diabetic Retinopathy Study" (5) and the "Macular Photocoagulation Study"(6).

Unfortunately, this standard logarithmic visual acuity chart uses 10 English letters, originally proposed by Sloan in 1953 and called "Sloan Letter" (7), as the optotypes. So the visual acuity chart cannot be used universally, especially in countries such as Thailand where English is used only as a second language. Thailand has its own language and alphabet. The objective of this study was to evaluate whether the logarithmic visual acuity chart with Thai letters as optotypes, constructed and designed properly in the same principle as the standard chart, can be used for measuring visual acuity.

MATERIAL AND METHOD

Subjects and study design

Subjects without any ocular disease aged between 18 and 80 years old were included in the study. Subjects with refractive errors were also included. All subjects used only their right eyes reading both the Thai and standard logarithmic visual acuity charts without any refractive correction. Subjects who could not read English or could read fewer than 3 out of 5 of the largest letters in either chart were excluded from the study. A number of subjects came back to have second readings with the same method and situation as the first readings a week later.

The subjects were divided into 2 approximately equal groups: the "Thai" group, the group of subjects who read the Thai chart first, and the "English" group, the group of subjects who read the standard chart first.

For prevention of bias, a coordinator who did not know the meaning of visual acuity and the purpose of the study was arranged to conduct all the readings by the subjects. During the test, all subjects

were placed 4 meters from the chart and started reading the letters from the top line of the visual acuity charts. If they were not sure what a letter was, they were allowed to guess. If subjects read all the letters in a line incorrectly, the test was stopped. The coordinator would remove the chart from the standard illuminated light box[8,9] and replace it with another chart. If the first chart was the standard chart, the second chart would be the Thai chart and vice versa. All readings from each subject were recorded on data sheets and then interpreted as visual acuity scores.

The visual acuity score in this study was categorized into two types: the Snellen score and the ETDRS score. The former was defined by the smallest "line" from which subjects could read at least 3 out of 5 optotypes correctly, the latter was defined by counting every "letter" the subject read correctly and processing them using the formula: 1.1-(Tc x 0.02) when Tc was the number of letters read correctly from the whole chart and each letter had a score of 0.02[4].

The Thai chart design

The design for the Thai logarithmic visual acuity chart has the same principle as the standard chart except for Thai letters as the optotypes. (Fig. 1) The size of the chart, the size of all optotypes, the number of optotypes in each line, the space between optotypes, the space between the edge of the chart to the outermost optotypes, the space between line and the number of lines were the same.

The Thai alphabet design

There are 44 letters in the Thai alphabet, which can be classified into several groups by their characteristics[10]. However, there are 11 letters that can fit into a square. They are ก ถ ค ด จ ธ ผ ย ล ว อ 10 letters from this group were chosen as the optotypes on the Thai chart, the letter ถ was left out because its character is too similar to the letter ก

The authors designed each of the 10 Thai letters using the same principle as Sloan letters. The stripe of each is one-fifth of the letter size. Each part of each Thai letter such as its head, its vertical,

Fig. 1. The Thai logarithmic visual acuity chart.

horizontal, oblique and circular line can be fitted into a small unit of the 5 x 5 grid covering the whole letter. (Fig. 2)

Furthermore, the authors also studied the difficulty scores of the 10 Thai letters and arranged them so that each line in the chart had approximately the same difficulty score.

Sample size calculation

Although both Snellen and ETDRS scores were studied, the authors focused on the latter as the main outcome measurement. From the pilot study[10], it was found that the standard deviation of the paired difference between the ETDRS scores from the standard and Thai charts was 0.085. The authors allowed the difference between the score from both charts in this study to be the smallest countable score, which was 0.02 or one letter of the ETDRS score. The power of the statistical test was set at 80 per cent. The sample size, calculated by using the paired *t*-test, was approximately 150 samples.

RESULTS

There were 153 subjects enrolled in this study. The average age of the subjects was 32 years old. There were 62 males and 91 females. There were 78 subjects in the "English" group and 75 subjects in the "Thai" group. There were 27 subjects whose visual acuity scores could be compared between the first and second reading one week later.

The Snellen score

Since the Snellen score from the logarithmic visual acuity chart has 14 individual scales or 14 nominal numbers, the authors chose weighted Kappa as a statistical test to analyze the agreement between the scores from both charts. As in Table 1, a high agreement was found between the Snellen scores from both charts in all groups of subjects. The weighted Kappa in overall subjects (n = 153) was 0.7375, in the "Thai" group (n = 75) was 0.7432 and in the "English" group (n = 78) was 0.7285. Even in a group of subjects who had the second reading (n = 27), a high agreement of weighted Kappa was still found between the first and second reading. They were 0.7282 and 0.7304 in scores from the standard and Thai charts respectively. (Table 1)

The ETDRS score

Very high correlations were found, which were statistically significant, when compared with the ETDRS scores from both charts in all groups of subjects. The paired correlation between the scores from both charts overall was 0.947, in the "Thai" group it was 0.955 and the "English" group it was 0.941.

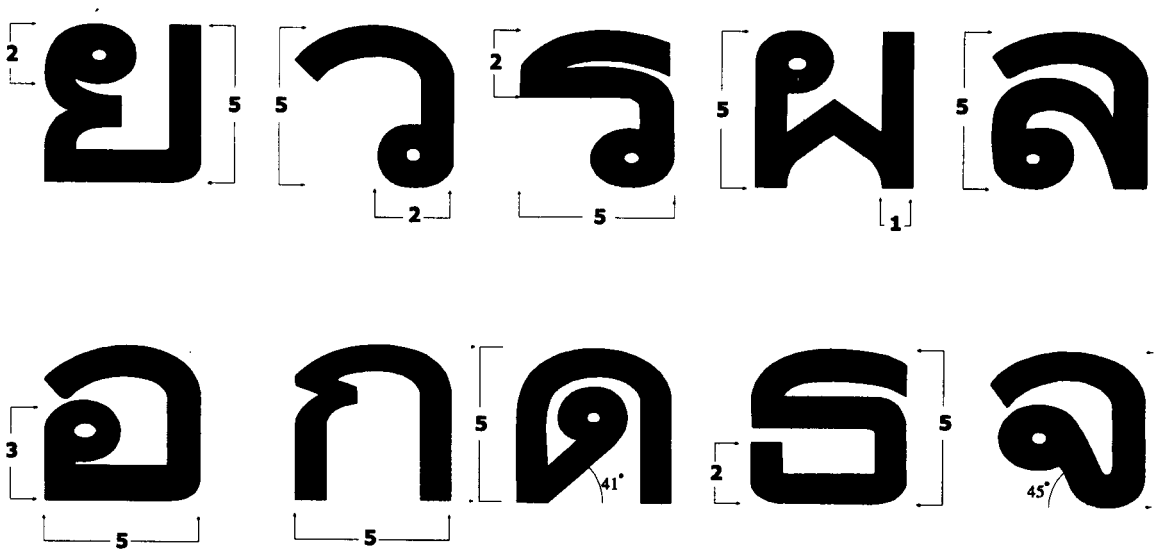

Fig. 2. The design of Thai letters used in the chart.

Table 1. The weighted Kappa of the Snellen visual acuity score.

The agreement between	Subgroup	Number of subjects	Weighted Kappa score	95% CI	
				Lower	Upper
The standard and Thai chart	Overall	153	0.7375	-0.2570	1.7319
	"Thai"	75	0.7432	-0.6555	2.1419
	"English"	78	0.7285	-0.6204	2.0712
The first and second reading	Standard chart	27	0.7282	-0.9595	2.4158
	Thai chart	27	0.7304	-1.0248	2.4855

Table 2. Paired correlations of the ETDRS score.

The correlation between	Subgroup	Number of subjects	Correlation	P-value
The standard and Thai chart	Overall	153	0.947	0.000
	"Thai"	75	0.955	0.000
	"English"	78	0.941	0.000
The first and second reading	Standard chart	27	0.952	0.000
	Thai chart	27	0.962	0.000

Table 3. Mean EDTRS scores of all subgroups.

Group	Score	Number of subjects	Mean ± SD
All Subjects	Standard chart	153	0.1027 ± 0.2574
	Thai chart	153	0.1304 ± 0.2576
"Thai" first reading	Standard chart	75	0.0995 ± 0.2659
	Thai chart	75	0.1307 ± 0.2547
"English" first reading	Standard chart	78	0.1059 ± 0.2507
	Thai chart	78	0.1301 ± 0.2620
Subjects for repeatability of the score, Thai chart	First reading	27	0.1793 ± 0.3119
	Second reading	27	0.1748 ± 0.3191
Subjects for repeatability of the score, English chart	First reading	27	0.1800 ± 0.3138
	Second reading	27	0.1422 ± 0.3239

(Table 2) Very high correlations were also found, which were statistically significant in a group of subjects who had the second reading. The paired correlations were 0.952 and 0.962 in the standard and Thai charts respectively. (Table 2)

The mean ETDRS score of all subjects from the standard chart was 0.1027 and from the Thai chart it was 0.1304. (Table 3) The difference between these mean scores was statistically significant, $p<0.0001$. (Table 4) In the "Thai" group, the mean score from the standard chart was 0.0995 and that from the Thai chart was 0.1307. (Table 3) The difference between these mean scores was also statistically significant, $p=0.001$. (Table 4) But in the "English" group, the mean score from the standard chart was 0.1059 and that from the Thai chart was 0.1301. (Table 3) The difference between these mean scores was not statistically significant, $p=0.18$. (Table 4) In subjects who had second readings, the mean score from the standard chart of the first reading was 0.1800 and that of the second reading was 0.1422. (Table 3) The difference between these mean scores was not statistically significant, $p=0.062$. (Table 4) The mean score from the Thai chart of the first reading was 0.1793 and that of the second reading was 0.1748. (Table 3) The difference between these mean scores was also not statistically significant, $p=0.794$. (Table 4)

DISCUSSION

Although the National Academy of Sciences-National Research Council Committee on vision of

Table 4. The paired *t*-test of the EDTRS score.

The paired *t*-test between	Subgroup	Paired Differences				t	P-value
		Mean	SD	95%CI			
				Lower	Upper		
The standard and Thai chart	Overall	-0.0276	0.0837	-0.041	-0.0142	-4.079**	0.000
	"Thai"	-0.0312	0.079	-0.049	-0.013	-3.42*	0.001
	"English"	-0.0242	0.0884	-0.0441	-0.0042	-2.413	0.18
The first and second reading	Standard chart	0.0378	0.1007	-0.0776	0.0020	-1.950	0.062
	Thai chart	0.0044	0.0876	-0.0391	0.0030	-0.264	0.794

* Significant at p-value <0.01
** Significant at p-value <0.001

the United States recommended using the Landolt ring as the standard optotype for visual acuity measurement[11], it is more practical to use Sloan letters [11] and the standard logarithmic visual acuity chart uses them as the optotype[2,4]. There are a few studies using letters of other languages as the optotype[12-15]. The characters of Thai letters are much different from English but the results from this study suggest the possibility of using them as the optotype in a visual acuity chart. Appropriate Thai letters can be selected and designed in the same principle as the design of the Sloan letters, if the size of the specific Thai letters and their stripes are equal to those of the Sloan letters used in the standard logarithmic visual acuity chart line by line. The Thai letters in each line should subtend the same visual angle as the Sloan letters in the subjects' eyes[16].

The authors also calculated the difficulty scores of the 10 Thai letters and used such scores to arrange the letters so that each line had approximately the same difficulty score. Such scores in the Thai chart had 1.24 standard deviation and 4.10 range, while the scores in the standard chart had 1.40 standard deviation and 4.7 range[4].

The increment of size of Thai letters in adjacent lines had a value of 0.1 log units of the ETDRS visual acuity score. This means the size of the letters in any line will be 1.26 times the size of letters in the lower line[17]. Of all features involved in the visual acuity chart design, the amount of size change attributed to letters in each line was one of the most important factors for obtaining the lowest test-retest variability of visual acuity scores[18].

In the Snellen score of this study, the high agreement between the standard and Thai charts was sustained no matter whether subjects read the standard or Thai chart first and the high agreement was also sustained between the first and second measurements of the Snellen score from both standard and Thai charts. This may be explained by the method of Snellen scoring. It is not required to count all the correct or incorrect readings to each optotype because the Snellen score is defined by the correctness of reading the whole line. So it is considered "coarse"[19-21]. However, the 14 levels of the Snellen score in a logarithmic visual acuity chart are twice as many as the 7 levels of a Snellen visual acuity chart. Therefore, if the Snellen score is used in clinical practice, the score from a logarithmic chart will give more detail. Furthermore, if the results from this study are applied, the Snellen score from the Thai logarithmic visual acuity chart should give a similar value as the standard logarithmic chart. However, this traditional Snellen score has a higher test-retest variability than the ETDRS score[19]. It is recommended to use the ETDRS score in research studies[4,22].

Although the ETDRS scores from both charts correlated very well in all groups of subjects, the mean ETDRS scores between both charts were significantly different in the "Thai" group, but not in the "English" group. The Thai letters were somehow harder to identify than English. In reading the first chart, which the subjects were not familiar with, the difficulty of optotypes may have played a major role in determining visual acuity scores. In reading the second chart, the subjects were already familiar with the chart format so they tended to get better scores[4]. The subjects in the "Thai" group had to face the letters that were more difficult to recognize in an unfamiliar chart format first.

However, the amount of difference between the mean ETDRS scores was small. In the overall group, the difference was 0.028, which was roughly 1.4 letters of the ETDRS score. In the "Thai" group, the amount was 0.031, which was also roughly 1.55

letters. In the "English" group, the amount was 0.024, which was roughly 1.2 letters. It was also noted that ETDRS scores obtained from the Thai chart were higher than the standard chart in all groups of subjects. This also suggests that Thai letters are harder to recognize than English.

In terms of the test-retest variability of the ETDRS score, although the sample was not enough, some trends could still be recognized. The second mean ETDRS score obtained from the same chart one week later had a lower figure. This means subjects can read letters in both charts better in second readings, which is the same finding as other studies regarding test-retest reliability of visual acuity scores (4). The difference of the mean ETDRS scores between the first and second reading from the standard chart was 0.038 or roughly 1.9 letters, the paired differences standard deviation being 0.1 or roughly 5 letters (1 line). The difference between the mean ETDRS score of the first and second reading from the Thai chart was 0.04 or 2 letters, the paired different standard deviation being 0.87 or roughly 4.3 letters. These standard deviations between the two charts were not much different but they were slightly higher than other studies(2,18-21,23). The standard deviations in those studies were about 2-3 letters. This may be explained by the variety of subjects in this study. The authors also included subjects whose Snellen visual acuity scores were not 20/20 while others included only subjects whose scores were 20/20.

Furthermore, this study focused on subjects between 18-80 years of age without any ocular disease. All subjects were tested without any refractive correction so that the authors could compare visual acuity scores between both charts in a variety of conditions. However, a further study that includes subjects with ocular disease with more subjects for study of test-retest variability of visual acuity score would be useful.

While the Snellen score from the Thai logarithmic visual acuity chart is in high agreement with the standard chart, the ETDRS score is different. Such a score may be different from the standard chart in terms of statistical analysis but the difference is small and the test-retest variability of the score from the Thai chart tends to be low. This suggests that the ETDRS score from the Thai chart for monitoring the ETDRS visual acuity score in the same subject in research studies can be used.

ACKNOWLEDGEMENTS

This study was supported by grants from the Research and Ethics Committee of Rajavithi Hospital. The authors wish to thank Ratthajak Potharam, B.F.A., instructor in the Department of Visual Arts, Faculty of Fine and Applied Arts, Rangsit University for designing the Thai letters used in this study, and also Dr. Julian Poulter of the Department of Mathematics, Faculty of Science, Mahidol University for editing the manuscript.

(Received for publication on February 14, 2002)

REFERENCES

1. Snellen H. Probebuchstaben zur Bestimmung de Sehscharfe. Utrecht: PW van de Weijer, 1862.
2. Bailey IL, Lovie JE. New design principles for visual acuity letter chart. Am J Optom Physiol Opt 1976; 53: 740-5.
3. Westheimer G. Scaling of visual acuity measurements. Arch Ophthalmol 1979; 97: 327-30.
4. Ferris FL III, Kassoff A, Bresnick GH, Bailey I. New visual acuity chart for clinical research. Am J Ophthalmol 1982; 94: 91-6.
5. Early Treatment Diabetic Retinopathy Study Group. Photocoagulation for diabetic macular edema. Arch Ophthalmol 1985; 103: 1796-806.
6. Macular Photocoagulation Study Group. Visual outcome after laser photocoagulation for subfoveal choroidal neovascularization secondary to age-related macular degeneration. The influence of initial lesion size and initial visual acuity. Arch Ophthalmol 1994; 112: 480-8.
7. Sloan LL, Rowland WM, Altman A. Comparison of three types of test target for the measurement of visual acuity. Q Rev Ophthalmol 1952; 8: 4-16.
8. Ferris FL III, Sperduto RD. Standardized illumination for visual acuity testing in clinical research. Am J Ophthalmol 1982; 94: 97-8.
9. Ferris FL III, Bailey IL. Standardizing the measurement of visual acuity for clinical research studies. Guidelines from the eye care technology forum. Ophthalmology 1996; 103: 181-2.
10. Ruamviboonsuk P. The Thai language "ETDRS" visual acuity chart. The 3rd Thailand-Japan Joint Meeting on Ophthalmology: Abstract Book 1999: 31.
11. National Academy of Sceinces-National Research Council Committee on Vision. Recommended standard procedures for the clinical measurement and specification of visual acuity. Adv Ophthalmol 1980; 41: 103-48.
12. Al-Mufarrej MM, Abo-Hiemed FA, Oduntan AO. A new arabic distance visual acuity chart. Optom Vis Sci 1996; 73: 59-61.
13. Wildsoet CF, Wood JM, Hassen S. Development and validation of a visual acuity chart for Australian Aborigines and Torres Strait Islanders. Optom Vis Sci 1998; 75: 806-12.
14. Johnston AW. New visual acuity tests using Chinese characters and the log MAR principle. Singapore Med J 1985; 26: 448-55.
150. Lewis JM, Smith TJ. Digital visual acuity test using calculator-type numerals with geometric gradation. Ophthalmology 1987; 94: 130-5.
16. Westheimer G. Visual Acuity, Adler's Physiology of the Eye, 9th ed. St.Louis: Mosby, 1992: 531-47.
17. Schechter RJ. New visual acuity charts. Am J Ophthalmol 1983; 95: 122-3.
18. Raasch WT, Bailey IL, Bullimore MA. Repatability of visual acuity measurement. Ophthalmol Vis Sci 1998; 75: 342-8.
19. Vanden Bosch ME, Wall M. Visual acuity scored by the letter-by-letter or probit methods has lower retest variability than the line assignment method. Eye 1997; 11: 411-7.
20. Bailey IL, Bullimore MA, Raasch TW, Taylor HR. Clinical grading and the effects of scaling. Invest Ophthalmol Vis Sci 1991; 32: 422-32.
21. Arditi A, Cagenello R. On the statistical reliability of letter-chart visual acuity measurements. Invest Ophthalmol Vis Sci 1993; 34: 120-9.
22. Lovie-Kitchen JE. Validity and reliability of visual acuity measurements. Ophthalmic Physiol Opt 1988; 8: 363-70.
23. Elloitt DB, Sheridan M. The use of accurate visual acuity measurements in clinical anti-cataract formulation trials. Ophthalmic Physiol Opt 1988; 8: 397-401.

แผ่นวัดสายตาลอการิทึมภาษาไทย

ไพศาล ร่วมวิบูลย์สุข, พ.บ., มนต์ทิพย์ เทียนสุวรรณ, ปร.ด.***

วัตถุประสงค์ : เพื่อประเมินค่าความชัดเจนของสายตา (visual acuity scores) ที่ได้จากการวัดด้วยแผ่นวัดสายตาลอการิทึมภาษาไทย และค่าที่ได้จากแผ่นวัดมาตรฐาน

แบบการวิจัย : การวิจัยเปรียบเทียบโดยไม่มีการสุ่มตัวอย่างในทางคลินิก

ผู้เข้าร่วมวิจัยและวิธีการ : ผู้ไม่มีโรคตาใด ๆ และไม่ได้รับการแก้ไขภาวะสายตาผิดปกติ จำนวน 153 คน อายุระหว่าง 18 ถึง 80 ปี ผู้สามารถอ่านภาษาอังกฤษ และอ่านตัวอักษรใหญ่สุดของแผ่นวัดทั้งสองแบบ ได้ถูกต้องอย่างน้อย 3 ใน 5 ตัว ได้รับการวัดความชัดเจนของสายตาในตาขวา ด้วยแผ่นวัดสายตาทั้งสองแบบ ผู้เข้าร่วมวิจัย 27 คนกลับมารับการวัดครั้งที่สองภายหลังจากการวัดครั้งแรก 1 สัปดาห์

ค่าหลักที่ใช้ในการประเมิน : ค่าความชัดเจนของสายตาที่ได้จากแผ่นวัดทั้งสองแบบ ถูกแบ่งออกเป็นค่าชนิด "Snellen" และค่าชนิด "ETDRS" ใช้ค่า weighted Kappa สำหรับการเปรียบเทียบเชิงสถิติของค่า "Snellen" และใช้ paired *t*-test สำหรับการเปรียบเทียบเชิงสถิติของค่า "ETDRS"

ผลการวิจัย : ค่าความชัดเจนของสายตาชนิด "Snellen" จากแผ่นวัดทั้งสองแบบ มีความสอดคล้องกัน ทั้งในการเปรียบเทียบค่าจากการวัดครั้งแรก ($k = 0.7375$) และการเปรียบเทียบระหว่างการวัดครั้งแรกกับครั้งที่สองสำหรับค่าที่ได้จากแผ่นวัดสายตาภาษาไทย ($k = 0.7304$) และค่าจากแผ่นมาตรฐาน ($k = 0.7282$) ส่วนค่าความชัดเจนของสายตาชนิด "ETDRS" จากแผ่นวัดสายตาทั้งสองแบบ มีค่าไปในทิศทางเดียวกัน ทั้งในการเปรียบเทียบค่าจากการวัดครั้งแรก ($r = 0.947$) และการเปรียบเทียบระหว่างการวัดครั้งแรกกับครั้งที่สองสำหรับค่าที่ได้จากแผ่นวัดภาษาไทย ($r = 0.962$) และแผ่นมาตรฐาน ($r = 0.952$) เมื่อเปรียบเทียบค่าเฉลี่ยของค่าความชัดเจนของสายตาชนิด "ETDRS" จากการวัดครั้งแรก ระหว่างแผ่นวัดทั้งสองแบบ พบว่ามีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.0001$) แต่ค่าเฉลี่ยของค่าความชัดเจนของสายตาชนิด "ETDRS" ที่เปรียบเทียบระหว่างการวัดครั้งที่หนึ่งและสอง ไม่แตกต่างกัน ไม่ว่าจะเป็นค่าที่ได้จากแผ่นภาษาไทย ($p = 0.799$) หรือค่าจากแผ่นมาตรฐาน ($p = 0.62$)

สรุป : ค่าความชัดเจนของสายตาชนิด "Snellen" ที่ได้จากแผ่นวัดทั้งสองแบบน่าจะใช้ทดแทนกันได้ ส่วนค่าชนิด "ETDRS" จากแผ่นวัดภาษาไทย แม้จะแตกต่างกับแผ่นวัดมาตรฐาน แต่ค่าจากแผ่นภาษาไทยก็มีแนวโน้มที่จะให้ความแปรปรวนในการวัดซ้ำน้อย ซึ่งน่าจะใช้ในการติดตามค่าความชัดเจนของสายตาชนิด "ETDRS" ที่เปลี่ยนแปลงในตัวผู้ป่วย โดยเฉพาะในการทำวิจัยได้

คำสำคัญ : ค่าความชัดเจนของสายตา, แผ่นวัดความชัดเจนของสายตาแบบลอการิทึม, ไทย

ไพศาล ร่วมวิบูลย์สุข, มนต์ทิพย์ เทียนสุวรรณ
จดหมายเหตุทางแพทย์ ฯ 2545; 85: 673–681

* กลุ่มงานจักษุวิทยา, โรงพยาบาลราชวิถี,

** ภาควิชาคณิตศาสตร์, คณะวิทยาศาสตร์, มหาวิทยาลัยมหิดล, กรุงเทพ ฯ 10400