Innovations

Construction and Validation of LogMAR Chart in Chinese

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Abstract: *Purpose: Chinese is one of the most widely used languages globally. This experimental research was conducted to design, construct and validate a logMAR chart with Chinese characters for distance visual acuity measurement.* ***Methods:*** *Chinese characters made up of four and five strokes which were often repeated in the standard three textbook were selected for the legibility experiment. The selected characters were then fitted into a 5x5 grid using CorelDRAW X7 software by individual stroke generation. The legibility experiment was carried out using the Strong and Woo (1985) method. Nine Chinese characters of similar legibility scores were used to construct the chart for a testing distance of 4 meters. The validity and repeatability of the chart were then compared to the standard English logMAR chart. Repeatability was measured after 5 min and after 1 week.* ***Findings:*** *The newly constructed logMAR chart in Chinese when compared with the Standard English logMAR chart showed a mean visual acuity difference of 0.08 ± 0.09 logMAR. Visual acuity obtained using the logMAR chart in Chinese were better compared to the Standard English logMAR chart. The limits of agreement between the logMAR chart in Chinese and the standard English logMAR chart was found to be -0.10, 0.26. The test-retest results after 5 minutes and after 1 week showed a difference of 0.03 ± 0.07 logMAR. The limits of agreement between the baseline and five minutes were -0.06, 0.11, and between baseline and one week later was -0.12, 0.18.* ***Conclusions:*** *The newly constructed logMAR chart in Chinese has good repeatability. The differences in the visual acuity obtained between the two charts were within acceptable limits. The newly constructed logMAR chart in Chinese can be used for measuring visual acuity in a clinical setup and for visual acuity screening for the Chinese-speaking population.*

Keywords*: 1. LogMAR 2. Visual Acuity 3. Chinese 4. Legibility*

1. Introduction

Visual acuity (VA) is defined as the sharpness of the visual image perceived (1). VA is quick and easy to perform, useful to detect ocular abnormalities and it helps to monitor the progression of a disease and is amenable to some treatments (2). The Snellen chart is a commonly used visual acuity chart clinically. Construction of logMAR chart has overcome the limitation of the Snellen chart. The letters in logMAR chart are almost of equal legibility, each row has 5 optotypes arranged in fourteen rows, and has consistent spacing between letters and rows, proportional letter size, equal logarithmic intervals in the progression of letter sizes (3). The chart was modified to an Early Treatment Diabetic Retinopathy Study (ETDRS) based on study of standardizing the measurement of visual acuity for clinical research (4). Measurement of visual acuity obtained from logMAR are two times repeatable compared to the measurement obtained from Snellen chart (5).

2. Literature Review

A small sample of letters are sufficient to represent the spatial complexity in phonics-based language. This is because they have regular spatial complexity. This method has been used widely in creating visual acuity charts in different languages such as English, German, Thai, Gujarati and Arabic (6–11). However, this cannot be applied to non-alphabetical language like Chinese. The spatial complexity of Chinese is in a broad range and consists of many different strokes in the same square area. These strokes can be up to a maximum of fifty-two strokes for one single character. Therefore, testing of legibility in a small number of Chinese optotype cannot represent the legibility (12). A study done by Woo and Lo (1980) selected the simple characters and followed the Snellen principle. However, a large discrepancy was found in these simple Chinese characters (13). Legibility of characters with four and five strokes were the best among the rest of the characters with maximum strokes numbers up to ten (14).

Chinese is one of the common languages used all around the world. Chinese is different from English as every Chinese character has syllable and morpheme together (15). Although there are variations in the language like Mandarin, Cantonese, Gan, Jin, Hakka and more, -they all have a uniform script and are considered as a unit by the ISO 639-1 standard. Most of the Asian countries have Chinese-speaking population. This includes China, Taiwan, Hong Kong, Singapore, Macau, Indonesia (Java and Bali) and Malaysia. There are about 1.31 billion Chinese speakers around the world (16). According to WorkdData.com, Malaysia is home to 7.4% of Chinese speaking world's population (17).

A study reported that repeatability measurement of visual acuity with Snellen chart was extremely poor (18). Repeatability of visual acuity measurements are more precise by using the chart which are based on the logMAR principle. The measurement of logMAR acuity scores is done by scoring individual letter which provides more precise measurement (19). ETDRS chart is considered the "gold standard" for visual acuity chart in research and clinic design which commonly known as "logMAR chart".

3. Objective of the study

The objective of this studywas to construct, validate evaluate the repeatability of a visual acuity measurement using the newly designed logMAR chart in Chinese.

4. Methods of the Study

An experimental study was conducted to first design a logMAR chart in Chinese and then validate the newly constructed chart against standard English logMAR chart, followed by evaluating its repeatability. The study was conducted in three phases as follows:

Phase 1: Selection of characters, testing for legibility and construction of the chart.

The frequently repeated Chinese characters with four and five strokes from standard three Chinese textbook were chosen. A total of 94 characters out of the 198 characters which had a median of 14 and 11 for four and five strokes respectively were selected and were attempted to construct into a 5x5 grid using the CorelDRAW X7 software by individual stroke construction method. The characters consisted of at least one stroke that subtends one minute of an arc, while the remaining strokes could subtend 1 or >1 min of an arc. No specific font was used as it did not maintain same thickness overall and did not meet the min of an arc criterion. Table 1 below shows the characters which were successfully constructed.

Table 1: Characters successfully constructed following the criteria

No.	Characters	n	No.	Characters	n	No.	Characters	n
1	文	90	**11**	日	66	**21**	月	33
2	元	97	**12**	以	180	**22**	田	16
3	什	142	**13**	五	14	**23**	四	19
4	无	29	**14**	太	39	**24**	左	15
5	见	45	**15**	从	39	**25**	正	19
6	不	354	**16**	火	46	**26**	平	19
7	王	49	**17**	牛	19	**27**	主	31
8	开	69	**18**	水	72	**28**	由	22
9	中	93	**19**	化	37	**29**	立	21
10	木	21	**20**	云	16	**30**	白	25

n = number of times the characters are repeated

A focus group discussion was conducted where feedback and opinion from 5 individuals was used to eliminate the similar looking characters. The individuals were presented with the Chinese characters that are shown in table 1 and were asked to identify any similar looking characters and/or characters which looked confusing with other characters. A total of 14 characters from the 30 shown in Table 1 were selected after the focus group discussion. These selected 14 characters were tested for their legibility using the Strong and Woo (1985) method (20). The characters were shown in Power-Point slideshow thrice, with the size 5.8mm x 5.8mm which is equal to 0.0 logMAR in the center of screen with 100 % contrast. This power-point presentation was projected on a 15-inch MacBook Pro. The screen resolution at horizontal was set at 2880 pixels while at vertical was set at 1800 pixels and the rate of refresh was 2.8 GHz. The area of screen to display was 358.9mmx 247.1mm and the illumination of the room was 320 ± 53 lux. Subjects were seated at the distance of 4 meters initially with their best correction placed in the trial frame in addition to an optical defocus which was created by +1.00DS lens in front of the testing eye while the non-testing eye was occluded. If they were not able to read the characters at 4 meters, the testing distance was reduced to 3 meters and so on until they identified the characters correctly. Legibility was calculated with the formula as shown in equation 1 below:

…… Equation 1

$$\text{Relative legibility} = \frac{\text{Mean distance of each letter}}{\text{Mean distance for all letters}}$$

Characters with mean legibility and within the ±10% of the mean legibility were included in the chart. The selected optotypes were arranged randomly in 14 lines ranging from 1.00 logMAR to -0.30 logMAR with 5 optotypes in each row. Constant geometric progression which was 0.1 log unit (1.26x) was maintained. Spacing between the two letters was set to be the same size as the optotypes in that line. Distance of inter-row was set to be same as the size of optotypes in the subjacent line. The chart was 65cm vertically and 63cm horizontally with external luminance source between 122 -130 cdm^2.

Phase 2: Validation of the newly constructed logMAR chart in Chinese

Subjects who were bilingual, those knowing both Chinese and English and have good ocular health were recruited for this experiment. A coin was tossed to decide whether visual acuity was to be tested using the logMAR chart in Chinese or standard English LogMAR chart first. A coin was again tossed to decide whether unaided visual acuity on the right eye or left eye was to be measured. Subjects had to sit at four-meter distance from the chart with the eye level parallel to the chart. Subjects had to read the line from the top to the bottom and follow the standard procedure for VA testing. Cessation point was when they identified a character wrongly. VA was measured for the same eye using another chart to compare.

Phase 3: Repeatability of visual acuity measurements.

Repeatability of visual acuity was performed on a different group of subjects. This was done for one eye only and the testing eye was decided by tossing a coin. All subjects were required to have an unaided visual acuity equal to or better than 6/60 on the testing eye. Visual acuity was measured using the logMAR chart in Chinese at three different intervals which are baseline, after five minutes and one week later. Subjects were instructed to read the line from top to bottom following the standard procedure for VA testing. Cessation point was when they identified a character wrongly.

5. Results & Data Analysis

Phase 1:

Eleven subjects consisting of 4 males and 7 females with mean age 24.45 ± 2.11 years were included for the legibility experiment. The mean spherical equivalent refractive error of the testing eye was -2.74 ± 0.20 D. All subjects had a cylindrical refractive error of -0.50D or lower. The mean legibility score was 1.00 ± 0.16. Table

2 shows the mean legibility of the final nine Chinese characters which were included in the construction of the logMAR chart in Chinese© [Copyrights: CRYLY00011607]

Table 2: Legibility of selected Chinese Characters in LogMAR chart in Chinese

No.	Characters	Mean Legibility		No.	Characters	Mean Legibility
1	云	0.91		6	开	1.02
2	立	0.97		7	火	1.02
3	牛	0.98		8	正	1.07
4	不	0.98		9	王	1.11
5	平	1.00				

The selected 9 characters were arranged randomly in 14 lines (1.00 logMAR to -0.30 logMAR) with 5 characters each line. The line legibility ranged from the lowest 4.98 to the highest 5.11. The chart was printed on synthetic sticker and mounting board by using 4C ECO Solvent Inkjet Printing with 100% contrast to be used as an externally illuminated SEGi Chinese Logarithmic Visual Acuity Chartas shown in Figure 1®. [Trademark registered under Class 16: 2018000901]

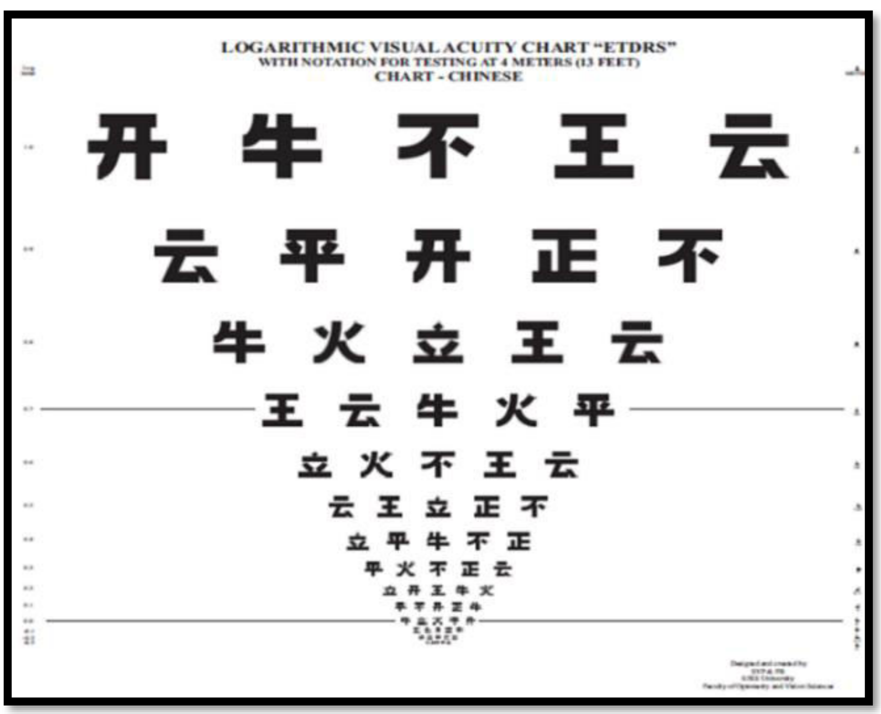

Figure 1: The newly constructed SEGi Chinese Logarithmic Visual Acuity Chart®

Phase 2:

The newly constructed logMAR chart in Chinese was validated against the standard English logMAR chart. A total of 81 subjects were recruited which included 49 females and 32 males with the mean age of 22 ± 2.00 years. The mean spherical equivalent refractive error of the testing eye was -3.48 ± 0.18 D. All subjects had a cylindrical refractive error of -0.50D or lower. The mean visual acuity obtained from logMAR chart in Chinese and English was 0.62 ± 0.42 and 0.54 ±0.42 logMAR, respectively. This indicated that the visual acuity obtained from the logMAR chart in Chinese was better than that obtained from the logMAR chart in English. The mean difference between the visual acuities obtained using the two charts was 0.08 ± 0.09 logMAR which equates to about 1 to 2 lines on a logMAR chart. Parametric one sample t-test was conducted to compare the mean VA which showed a statistically significant difference, t (81) = 7.716, p <0.01. The upper and lower limits of agreement were 0.258 and -0.101 respectively. The Bland and Altman plot was constructed to evaluate the limit of agreement as shown in Figure 2. The logMAR chart in Chinese was rejected statistically as it was difficult to by read by an average of four optotypes compared to the Standard English logMAR chart.

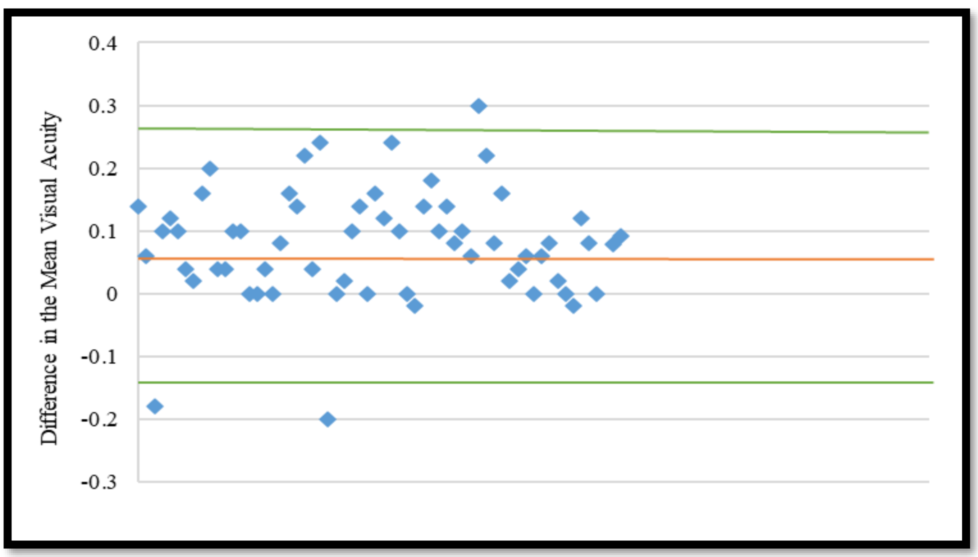

Figure 2: Bland and Altman plot to evaluate the validity of the newly constructed logMAR chart in Chinese compared to the standard English

logMAR chart. The upper limit and lower limits of agreement are plotted in the green lines.

Phase 3:

A total of thirty-eight subjects were enrolled for evaluating the repeatability of the newly constructed logMAR chart in Chinese. The mean age of the subjects was 21 ± 1.8 years old. The mean spherical equivalent refractive error of the testing eye was -2.38 ± 0.24 D. All subjects had a cylindrical refractive error of -0.50D or lower. The mean and standard deviation of visual acuity measurement at different time intervals are shown in Table 3 below

Table 3: Mean and standard deviation at different time intervals

Visual Acuity	Mean ± Standard deviation (logMAR)
Baseline	**0.58 ± 0.38**
5 minutes	**0.55 ± 0.38**
1 week	**0.55 ± 0.38**

The visual acuity measurement obtained was analyzed using repeated measures ANOVA. Mauchly's Test of sphericity indicated that the assumption of sphericity had been violated, χ^2 (2) = 12.798, $p < 0.05$. Therefore, a Huynh-Feldt correction was used. There was a significant effect on visual acuity measurement of logMAR chart in Chinese, F (1.59, 58.95) = 4.48, $p < 0.05$. Bonferroni post hoc test showed that the mean of logMAR value at baseline was poorer. Baseline (0.58 ± 0.06) to 5 minutes (0.55 ± 0.06) was statistically significant, $p = 0.02$. However, baseline to 1 week measurement (0.55 ± 0.06) was statistically not significant, $p = 0.08$.

Bland and Altman Plot were constructed to test the limit of agreement, the results show significant difference for baseline to 5 minutes ($p < 0.01$) and baseline to 1 week (p = < 0.05). Figure 3 shows the Bland-Altman plot for baseline and 5-minute measurements. The limits of agreement for the mean difference were (-0.06, 0.11) while figure 4 shows the Bland-Altman plot for baseline and 1 week. The limits of agreement for the mean difference were (-0.12, 0.18). Although it shows statically significant for the *p* value, but Lovie (1988) stated that acceptable range for the mean differences between the repeat measurements was range 0.02 ± 0.08.(5) The mean difference from this study falls inside the range of acceptable range for mean differences. So, it was statistically significant but clinically not significant.

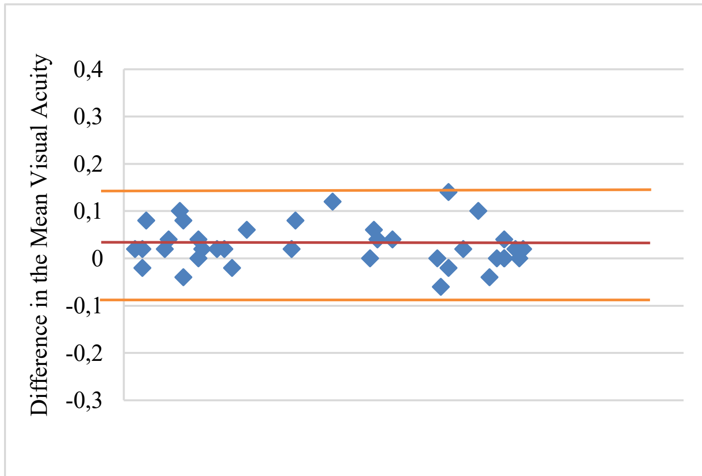

Figure 3: Bland-Altman Plot for difference in the mean visual acuity from baseline and after 5-minute measurements. The upper limit and lower limits of agreement are plotted in the green lines.

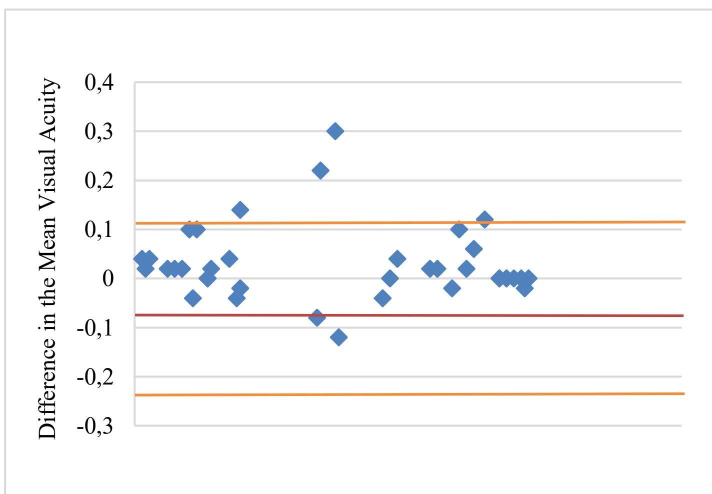

Figure 4: Bland-Altman Plot for difference in the mean visual acuity from baseline and after 1 week of measurements. The upper limit and lower limits of agreement are plotted in the green lines.

6. Discussion:

The Chinese characters selected for the study were from the Standard three Chinese textbook as the Chinese ethnic who went to Chinese primary school would be able to identify those Chinese characters. Previous researchers also selected Chinese characters that been used widely and unrelated to each other, and from an official character-frequency table of a press from Beijing (12,14).

The Tamil logMAR chart constructed previously had excluded the letters that have too many curves and those which could not fit in the 5x5 grid or the letters were similar looking with some other letters which could cause confusion (8). The present study agreed that similar looking optotypes could cause confusion as the focus group discussion conducted in present study found that similar looking characters cause confusion and individuals tend to guess rather than recognize the optotypes.

A few studies choose the font types that was commonly used in the reading materials or internet sources of their specific ethnic group (8,14,21), however in the present study, the characters were generated by constructing each stroke separately and individually which was the same as the Chinese LogMAR chart constructed by Woo and Lo 1980 (13). Strokes construction rather than font type chosen was because stroke construction allowed the stroke to subtend at least one minute of an arc evenly in the 5x5 grid.

Most of the studies conducted previously to construct a logMAR chart did not conduct focus group discussion. However, it is a kind of research methodology to recruit a small group of individuals for discussion on a particular topic to come out with the point of view for a better outcome (22). Focus group discussion involves open-ended questions and leads the participants to give comments on different aspects. The study showed that focus group discussion could help in the construction and design of new logMAR chart (23).

The legibility scores of the characters in the present study were in the range of 0.64 (easiest to identify) to 1.25 (hardest to identify). The nine selected characters to include in the chart were characters fell within 10% of the mean legibility. Tamil LogMAR chart also selected ten letters with the mean legibility of 1.01 (8). Another study constructed a Arabic chart by selecting twelve letters with about the same legibility of 1.00 (6). On the other hand, the optotypes included in the Gujarati LogMAR chart were based on the legibility value not more than 10% of the mean (7). The present logMAR chart was constructed following the criteria's and standards of Bailey and Lovie (1976) (24). Majority of the LogMAR chart followed the same standards (6–8).

The mean differences of the visual acuity obtained from Chinese and English LogMAR chart was 0.08 which corresponds to four optotypes. The maximum difference of VA from previous study when comparing the newly constructed Tamil logMAR chart and the ETDRS chart was 0.14 which was equivalent to 7 optotypes (8). However, they accepted their LogMAR chart to be compatible to ETDRS as the difference in the VA was fulfilled the standard set by Lovie-Kitchin (1988) (5). Similarly, a logMAR chart in Gujarati was constructed and validated against the modified Early Treatment of Diabetic Retinopathy Study logMAR chart. They found that the mean difference between the charts was 0.06 logMAR which was equivalent to 3 optotypes. They concluded that was clinically irrelevant with a few supports on the method to construct the chart (7). An Arabic chart was constructed and validated against the Emarah chart and E chart was well correlated with the Emarah chart. However, it did not correlate well with E chart (6) .

All three logMAR charts showed differences of VA obtained when they were compared to another alphabetical charts. These differences could be due to the complexity of the optotypes compared to the alphabetical charts. A study shows that the Chinese characters which have been frequently used were in lesser strokes (25). This was correlated with the findings from another study which shown that Chinese characters with four and five strokes were more recognizable than the Chinese characters with eight to ten strokes (14). Thus, the characters selected for this present chart were simple enough that Chinese speaking individual would be able to identify whereas it would be more complex if compared to alphabetical optotypes.

A study found that the VA obtained by Lea symbol chart was better than Bailey-Lovie chart by the average difference is 0.09 logMAR. This was because the Lea symbol chart was constructed with four symbols only, but Bailey-Lovie chart was constructed with ten optotypes. Thus, guessing is more likely in Lea symbol chart compared to Bailey-Lovie chart (26). The number of optotype of the present study is almost the same as Bailey-Lovie. Thus, guessing should not be a factor contributed to the difference of VA obtained from the two logMAR charts.

The subset memory of the letters on the chart will help the subject to improve their acuity scores on repeat measurement (27). In the present study, the visual acuity after 5 minutes improved by 2 to 4 optotypes. It is more likely to have a greater chance to improve the acuity score immediately after first measurement. A study also reported that that test-retest within 1 to 24 hours can cause significant improvement in visual acuity score (28). A study reported that the test-retest visual acuity measurement after five minutes showed significant difference (mean difference = 6.6 ± 1.5 letters) (27). which same as the present research. It was proved that the retest acuity score was improved due to letter subset memory.

The authors of the Tamil logMAR chart repeated the VA measurement five minutes after the first measurement, the mean difference was 0.02 ± 0.06 logMAR which mean 1 ± 3 letters differences but it was statistically not significant (8). It may be due to the complexity of Chinese characters compared to the Tamil characters. The Tamil logMAR chart was an internally illuminated chart while the logMAR chart in Chinese which use in current research was externally illuminated visual acuity chart. It is reported that illuminance can cause statistically significant effect on test-retest variability of visual acuity (29).

Similarly the authors of the logMAR chart in Gujrati reported 1 to 1.5 lines change in the VA score on repeat measurement on logMAR chart (7). According to another study, only 33% of subjects had equal acuity score on retest measurement, 13% of subjects showed different acuity score which was 2 lines or 2 lines above (18). It was also reported that acuity score on logMAR chart must more than 2 lines and above to be considered as a significant change (18). The mean difference in the present research for baseline to 5 minutes were 1.5 ± 2 letters (less than 1 line); baseline to 1 week were 1.5 ± 4 letters (less than 1.5 lines). So, this study shows statistically significant but clinically not significant.

For repeat measurement, it should not be more than 0.08 log unit (4 letters) for 95% limit of agreement. It showed a significant difference when the differences between the repeat measurement was 0.10 log units or 5 letters (19,30–34). In present research, baseline to 5 minutes, the limits of agreement for the mean difference were -3 to 6 letters; for baseline to 1 week, the limits of agreement for the mean difference were -6 to 9 letters. The differences between the repeat measurements were more than 5 to 7 letters. Therefore, it showed a statically significant difference.

Visual acuity evaluation in native language could be beneficial for the population to be comfortable with the language. Since the measures of visual acuity between the logMAR chart in Chinese and English are acceptable, the logMAR chart in Chinese can be used for measuring visual acuity and performing clinical refractions for the Chinese speaking population

7. Conclusions

In conclusion, the newly constructed logMAR chart in Chinese had some differences in VA measurement. The difference between visual acuity obtained using logMAR chart in Chinese and logMAR Chart in English were still within the acceptable range. The present chart can be used for vision screening, certain modifications in the chart such as arrangement of optotypes can be considered to reconstruct the chart and test for its validity and visual acuity.

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Disclosure:

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