The Effect of Refractive Status on Near Stereopsis in School-age Children

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ABSTRACT

Introduction: This study aims to evaluate the effect of refractive status on near stereopsis function among school-age children. **Methods**: A population-based cross-sectional study in 13 orphanages in Malang city with 334 respondents. Visual acuity (VA) and inter-eye line difference were measured using LogMAR of LVRC chart. Refractive status was determined using spherical equivalent (SE) of autorefractometer, classified into emmetropia, myopia and hypermetropia (low, moderate, and high). Near stereopsis was measured using TNO and Butterfly test in arcsecond and completion time also calculated. Data were analyzed using Kruskal-Wallis and Spearman test. **Results**: There were significant differences of refractive status and inter-eye line difference to both TNO and butterfly score and time (p<0.05). The group with more severe refractive status and more inter-eye line difference in VA have lower stereopsis score and longer completion time. There were no differences between the age group to both TNO and butterfly score and time (p>0.05). There was a positive correlation between TNO and butterfly test (p<0.05, r= 0.365). **Conclusion**: There is a significant difference of refractive status and inter-eye line difference on near stereopsis function in school-aged children. Stereopsis test may be beneficial for screening of refractive disorder.

Keyword: Children, refractive status, stereopsis.

ABSTRAK

Pendahuluan: Penelitian ini bertujuan untuk mengevaluasi korelasi status refraksi dengan stereopsis dekat pada anak usia sekolah. **Metode**: Penelitian potong lintang berbasis populasi pada 13 panti asuhan di kota Malang dengan jumlah responden 334 orang. Tajam penglihatan (VA) dan perbedaan baris antar mata diukur menggunakan LogMAR dari LVRC *chart*. Status refraksi ditentukan dengan *spherical equivalent* (SE) dari alat autorefraktometer, dibagi menjadi emetropia, miopia, dan hipermetropia (rendah, sedang, dan tinggi). Fungsi stereopsis dekat diukur dengan tes TNO dan Butterfly dalam *arcsecond*, serta dihitung waktu penyelesaian tes. Data dianalisis dengan uji Kruskal-Wallis dan Spearman. **Hasil**: Kelompok dengan status refraksi lebih berat dan perbedaan baris antar mata lebih besar pada VA memiliki nilai stereopsis lebih rendah dan waktu penyelesaian lebih panjang. Tidak terdapat perbedaan skor dan waktu tes TNO dan Butterfly di antara kelompok usia (p>0,05). Terdapat korelasi positif antara tes TNO dan *Butterfly* (p<0,05; r= 0,365). **Simpulan**: Terdapat perbedaan signifikan status refraksi dan perbedaan baris antar mata terhadap fungsi stereopsis dekat pada anak usia sekolah. Tes stereopsis dapat bermanfaat untuk deteksi gangguan penglihatan. **I Nyoman Surya Ari Wahyudi, Anny Sulistiyowati, Nanda Wahyu Anandita, Lely Retno Wulandari. Pengaruh Status Refraksi terhadap Stereopsis Dekat pada Anak Usia Sekolah.**

Keyword: Anak, status refraksi, stereopsis.

INTRODUCTION AND OBJECTIVE

Stereopsis is a binocular sensation of relative depth formed by the horizontal disparity of the image on the retina, which is the highest binocular function that creates a unique quality of vision. Stereopsis is part of fusion, namely the cortical merging of two images of one object from each eye to become a single perception. Good binocular vision function is very important to form stereopsis [1,2] Near stereopsis is the stereoacuity measured in near viewing distance, most of the instruments evaluating in 40 cm distance.[3] The assessment of stereopsis function defined as second of arc or arcsecond. One arcsecond is equal to 1/3600 of a degree.[4] There are two factors influencing stereopsis performance: the recognition speed which quantifies the complexity by the promptness of response for a disparity, and the robustness which quantifies the confidence of responses for a disparity. When the speed and robustness are delayed the stereoacuity levels are reduced.[5]

Poor stereopsis is associated with poor visual quality and reduced quality of work, especially in tasks requiring hand-eye coordination and visual motor skills.[6] Factors affecting stereopsis development are ocular conditions such as ametropia, aniseikonia, amblyopia, strabismus, nystagmus, aphakia, and monovision-and-monofixation syndrome.[5] It is estimated around 15%-20% population has some

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degree of stereopsis.[7] The study by Lam, *et al*, and Farwardin, *et al*, in Ahmadi, *et al*, (2018) showed that refractive disorders can reduce stereopsis function.[8]

Near stereopsis function test is the part of integral examination to the comprehensive assessment of sensory visual function in children.[9] This study aims to evaluate near stereopsis and refractive status, to help early detection of refractive errors, especially in children.

METHODS

The research is an analytic observational with a cross sectional study design. This study was approved by the Research Ethics Commission of the Faculty of Medicine, Universitas Brawijaya (number 327/EC/KEPK/11/2021).

The sampling used consecutive sampling method and data collection at 13 orphanages in Malang City from June to October 2021. Prior to the examination day, the respondent's parent/guardian was asked to sign an informed consent to take part in the study.

The research variables include age, refractive status, visual acuity, and near stereopsis function as assessed by the TNO (Toegepast Natuurwetenschappelijk Onderzoek) test and Butterfly test. The inclusion criterias were school-age children, age 6-18 years, present present, and able to complete all examinations. Exclusion criterias were inability to complete the examination and presence of pathologic condition in the eye (misalignment, infection, corneal and/or vitreous opacity, and pathologic condition of retina).[1,10]

Instruments used in this study include LVRC VA chart, Hand-held auto-refractokeratometer (ARK) Handyref, trial frame, trial lens, halogen direct Ophthalmoscope BXα-13A, handheld portable slit lamp, penlight, TNO stereo test book (19th ed), butterfly stereo acuity test P/N 1010, including red-green glasses for TNO examination, polarized spectacle for butterfly examination, and timer.
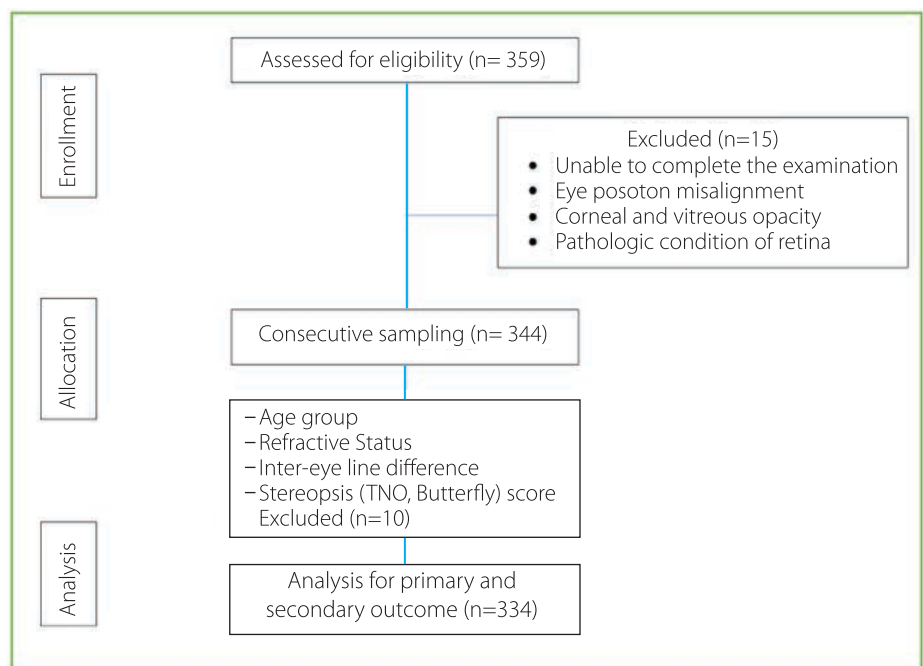
Prior to the examination, the respondent's name, age, and gender were recorded. Refractive status was assessed from the conversion of Handyref ARK examination to spherical equivalent then the result grouped into emmetropia, myopia, and hypermetropia.

Myopia is divided into mild (from less than 0 D to S-3.00 D), moderate (less than S-3.00 D to S-6.00 D), and high (less than S-6.00 D). Hypermetropia is divided into mild (less than S+2.00 D), moderate (more than S+2.00 D to +5.00 D) and high (more than S+5.00 D). VA examination was carried out using the LVRC chart and measured using the LogMAR scale
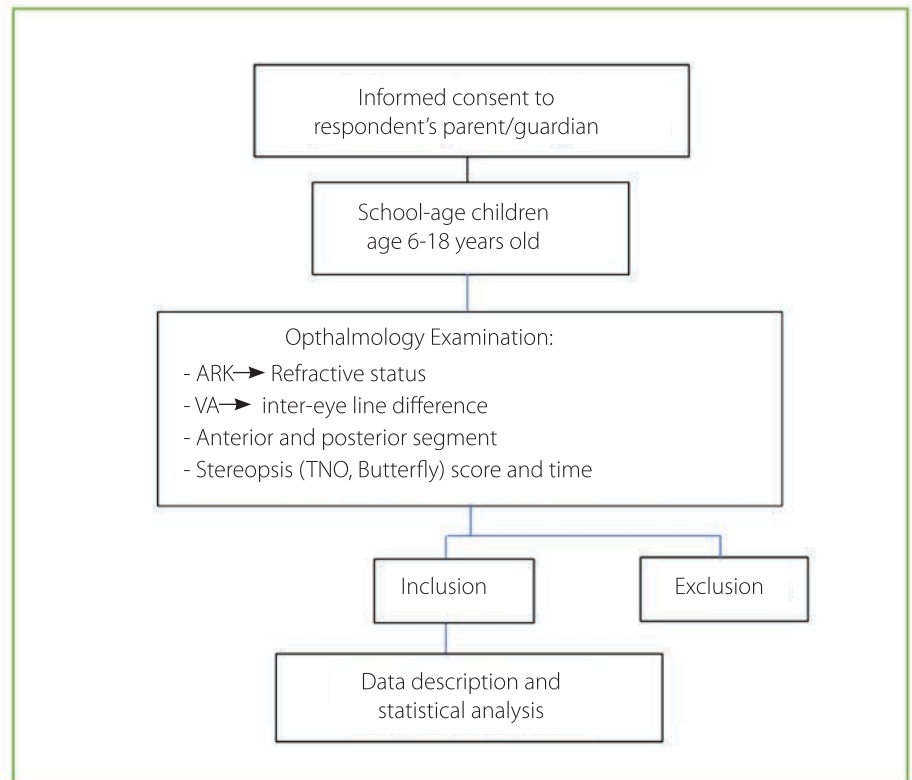
Scheme 1. Examination process flowchart.

Scheme 2. Recruitment data of the respondents.

listed on the chart. After the examination, respondents' line differences between their two eyes will be calculated and grouped into categories: no line difference, 1-2 lines, 3-4 lines, and more than 4 lines. Respondents then underwent anterior and posterior segment examination of the eye before near stereopsis tests.

Near stereopsis examination was carried out with TNO and Butterfly test, conducted in 40 cm distance in a well-illuminated room with uncorrected visual acuity. Prior to the examination, the respondent was given an explanation of the procedure for each test. The completion time is calculated from the beginning of the test until completion of the last plate, or the best plate that can be identified.

The examiner matched the respondent's interpretation with the answer key simultaneously. Both results were recorded separately in arcsecond (TNO score ranged from 480 to 60 arcsecond; butterfly score ranged from 400 to 20 arcsecond) and total completion time in second.

STATISTICAL ANALYSIS
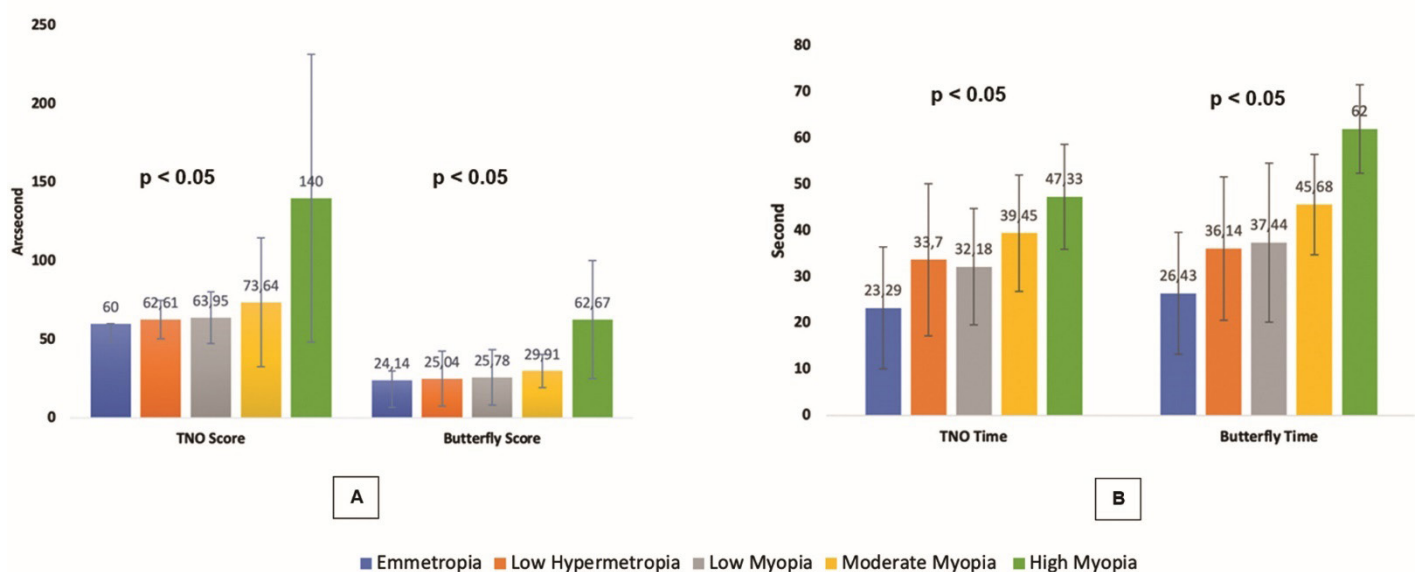The data was analyzed by SPSS 25 software. The descriptive analysis was presented in frequencies and percentages. Comparison of groups was calculated using Kruskal-Wallis test, and association between TNO and butterfly by Spearman test.

RESULTS
A total of 334 respondents met the inclusion criteria and were analyzed, described in **Table**.

The examination of the near stereopsis function used the TNO method. The mean value of 334 respondents was 64.91 ± 20.85 arcseconds in 32.92 ± 17.75 seconds, and on the butterfly examination, the average value was 26.20 ± 17.65 arcseconds in 37.71 ± 16.70 seconds. The result shows disparity between the measurements used, as mentioned in study by Zhao, *et al*, (2019).[11] None of the data from the groups met normal distribution. Nonparametric tests were used to analyze the data.

Table. Characteristics of the respondent.

	Data	Total	%
Gender	Male	157	47
	Female	177	53
Age	6-12 years	79	23.7
	13-15 years	156	46.7
	16-18 years	99	29.6
Refractive Status	Emmetropia	7	2.1
	Low hypermetropia	69	20.7
	Low myopia	233	69.8
	Moderate myopia	22	6.6
	High myopia	3	0.9
Inter-eye Line Difference	No Line Difference	260	77.8
	1-2 Line	55	16.5
	3-4 Line	12	3.6
	> 4 Line	7	2.1

Note: Hypermetropia status from SE of ARK is only low hypermetropia as no respondent have SE greater than S+2.00 D.

Figure 1. Differences in the mean value of stereopsis examination and completion time based on refractive status. (Blue= emmetropia; orange= low hypermetropia; grey= low myopia; yellow= moderate myopia; green= high myopia). The group with more severe refractive status has lower scores (A) and longer time (B) than the groups with less severe and normal status (The lower value, the better result).

Refractive Status and Stereopsis

The results for each near stereopsis examination and the completion time were presented in **Figure 1.** The data consists of 5 refractive status group, the lowest average score was in the high myopia group (TNO score 140.0 ± 91.65 arcsecond in 47.33 ± 11.37 second; Butterfly score 62.67 ± 37.50 arcsecond in 62.00 ± 9.54 second) and the best result was in the emmetropia group (TNO score 60.00 arcsecond in 23.29 ± 13.16 second; Butterfly score 24.14 ± 5.67 arcsecond in 26.43 ± 13.18 second). More severe refractive status leads to lower near stereopsis score and increased completion time.

An analysis by comparison test on near stereopsis score and time completion using the Kruskal-Wallis method obtained p-value <0.05 in every group. There is a significant difference in near stereopsis score and test completion time across refractive status.

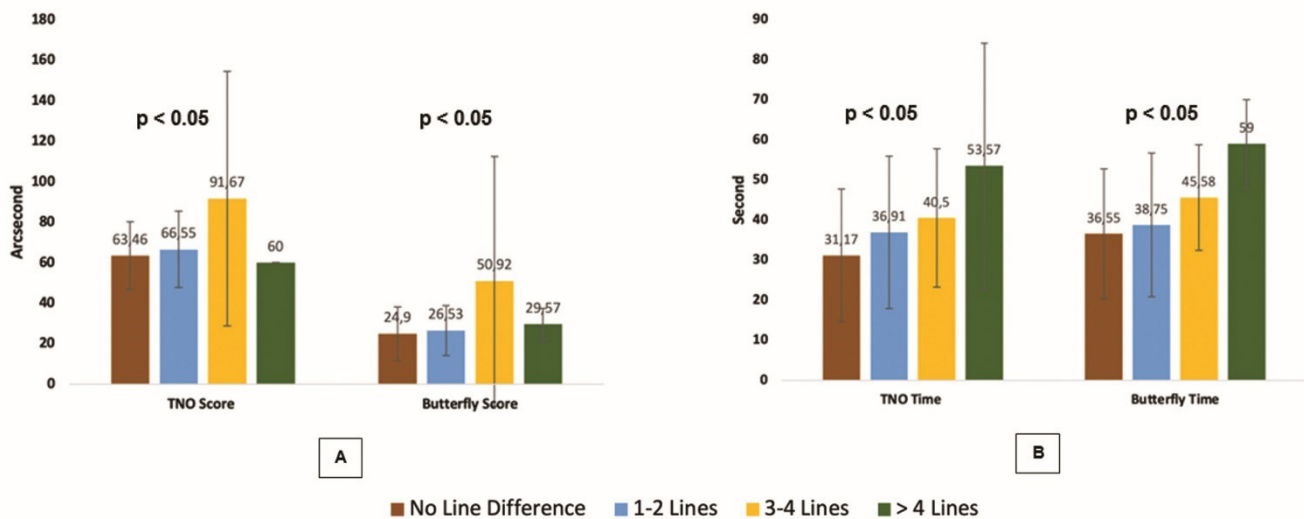## Inter-eye Line Difference and Stereopsis

The result of near stereopsis score and time completion with inter-eye line difference presented in **Figure 2**. The 3-4 line differences group have the lowest near stereopsis score (TNO score 91.67 ± 62.93 arcsecond; Butterfly score 50.92 ± 61.58 arcsecond), while the group with > 4 line differences have the

longest completion time (TNO time 53.57 ± 30.60 second; Butterfly time 59.00 ± 11.02 second).

Kruskal-Wallis test resulted p-value <0.05 in each group. There is a significant difference in stereopsis score and time with inter-eye line difference in this study, more inter-eye line differences tend to have a lower score and longer time to complete the near stereopsis test.

Age Group and Stereopsis

The analysis of TNO and butterfly score and time based on age group presented in

Figure 2. The mean score of stereopsis examination (A) and completion time (B) based on inter-eye line difference (Brown= no line difference; blue= 1-2 lines; yellow= 3-4 lines; green= >4 lines). More line differences show lower score and longer completion. (The lower the value, the better the result)
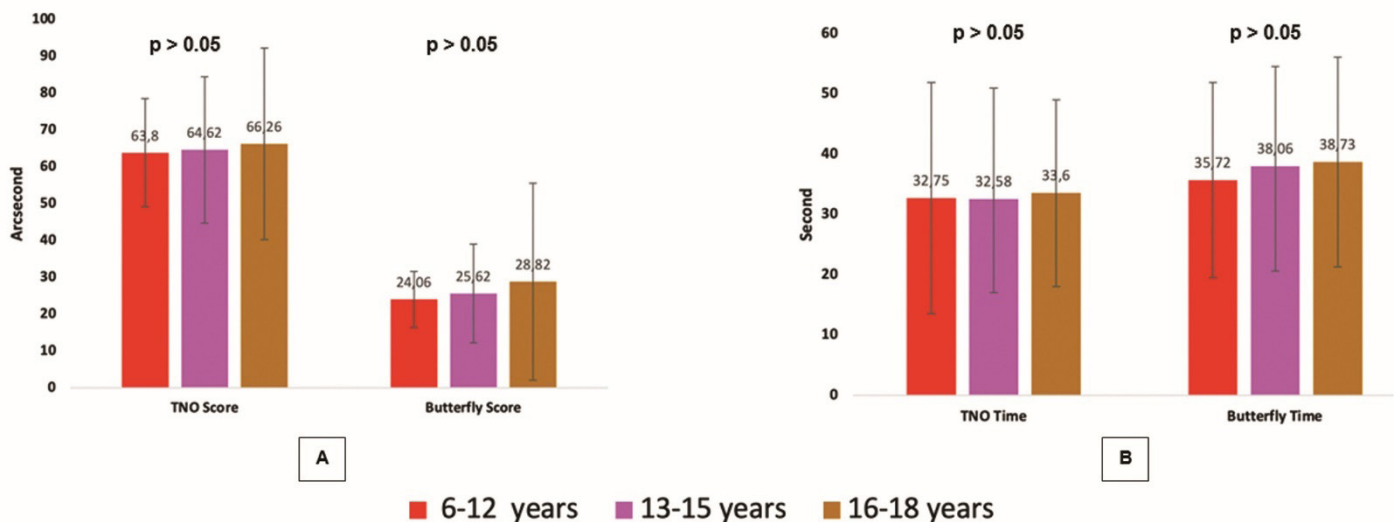
Figure 3. The mean score of near stereopsis (A) test and the time completion (B) for each age group (Red= 6-12 years; Purple= 13-15 years; brown= 16=18 years). Each age group have a similar test score and completion time.

Figure 3, the result shows a small discrepancy between 6-12, 13-15, and 16-18 years old group. Kruskal-Wallis test resulted in p > 0.05 in each age group. There is no significant difference in stereopsis score and completion time with age group. The outcome of each stereopsis test result and time is not influenced by the respondent's age.

Correlation of TNO and Butterfly Test
The correlation between TNO and butterfly test were analyzed with Spearman test. The result was a correlation coefficient r = 0.365 with a p value <0.05, there is a strong positive correlation with weak strength of relationship (0.3< r < 0.5).[12]

Both tests have positive value in measuring the near stereopsis function. TNO score increase will be followed by an increase in the score of butterfly test.

DISCUSSION
The stereopsis test has been suggested as an ideal test for visual screening because optical, motor and neural function in both eyes must be in working condition to achieve a normal stereoacuity.[1,2,13]

This main outcome of this study showed significant differences between refractive status and near stereopsis function in school-age children. Among all group of refractive status, the high myopia group has the lowest average stereopsis score and longest average completion time. Compared to recent study by Ahmadi, *et al*, (2018) on stereopsis function of 7-year-old primary school children in Iran, this study has a wider range in age group (6 to 18 years).[8] This study results are in line with Wajuhian, *et al*, (2019) and Ahmadi, *et al*, (2018) studies which reported a significant relationship between refractive errors and stereopsis function. [8,14] Results of other similar studies done in East China, Taiwan, and India were in line with this result.[15–17] Refractive error condition will reduce binocular function through inducing visual blur and impair the sensory fusion which leads to poor stereopsis.[6]

The analysis of inter-eye line difference and stereopsis function also showed significant result; the group with more line difference have a lower stereopsis score (**Table 3** and **Figure 2**); the group with 3-4 line differences had the lowest average near stereopsis

score. The group with >4 line differences has a slightly better score than the 3-4 line difference group but the completion time is longer. This difference is associated with anisometropic condition of respondent. This result is in line with study by Yang, *et al*, (2013) where anisometropia >1.00 D associated with significantly reduced stereoacuity in children.[17] Other study by Tilahun, *et al*, (2021) reported the inter-eye VA difference with stereopsis function after refractive error correction in 153 adults, more line difference is associated with reduced stereopsis function.[6] Study by Guo, *et al*, in 5780 children age 4 to 18 in Shandong, China with cycloplegic refraction also found that stereoacuity is significantly associated with higher inter-eye difference in best corrected visual acuity in logMAR.[15]

This study showed no significant difference of near stereopsis function by TNO and butterfly test with age (**Figure 3**); the stereopsis score and completion time of each test in every age group is consistent with small discrepancy. So, it can be concluded that the TNO and butterfly test are valid methods in this study to measure the near stereopsis function in school-age children. Study by Elamurugan, *et al*, (2022) on 222 respondents age 5-18 years old in assessing spectacle-corrected refractive error, found no statistically significant difference of stereopsis value across different age groups,[18] this result is in line with this study. A certain level of stereopsis can be measured in infants as early as 4 months of age.[19,20] Binocular

vision then matures during childhood and stereoacuity reaches the adult level between in age 4 years and up to 9-14 years, depends on the test used.[20] That recent study supports the validity of the stereopsis result as the respondent's age in this study (6-18 years old) is within the maturity range.

Beside the stereopsis score, this study also calculated time for the test. As the best of our knowledge, currently there are only a few studies examining the time of stereopsis test. A study by Rodriguez-Vallejo, *et al*, (2016) in measuring stereopsis at multiple distances showed the time spent for complete trial in around 30 seconds.[21] Other study by Sunina, *et al*, (2021) calculating the duration of stereopsis and visual acuity in horizontal acceleration shows the mean time completion of circle test stereoacuity when the subject is in static condition is 44.87 ± 6.62 second.[22] In this study, the average of TNO completion time from all respondents was 32.92 ± 17.75 seconds and the butterfly average was 37.71 ± 16.70 seconds. The average completion time needed for test is 30 to 40 second, and it can be the influenced by the refractive status and inter-eye line difference.

The secondary output in this study is to evaluate the TNO and butterfly test in measuring near stereopsis. We found a significant correlation - the increase of TNO score also followed by an increase in butterfly test (**Figure 4**). Weak correlation power may
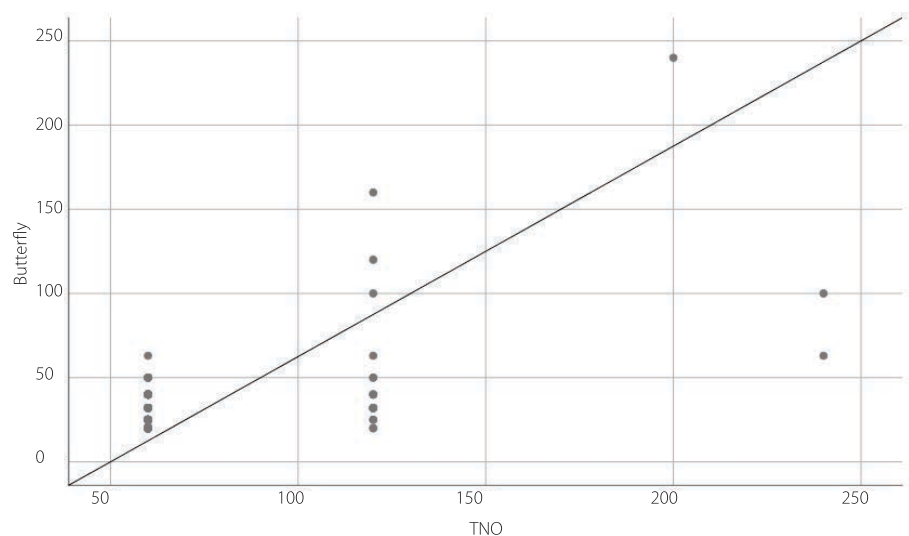
Figure 4. Scatter-plot distribution graphic of TNO and butterfly test. The diagonal line represents a positive correlation between two variables (TNO and butterfly).

be caused by high score disparity from both instruments.[11] The 19th edition of TNO test used in this study measure stereopsis score in 480, 240, 120, and 60 arcsecond, while the butterfly test measure score in 400, 200, 160, 100, 63, 50, 40, 32, 25, and 20 arcsecond. The TNO and butterfly stereo test are commonly used to measure near stereopsis function. Threshold with TNO tend to be higher than with other stereo tests.[23] Study by Karimian, *et al*, (2017) also used TNO and butterfly stereo test to measure stereoacuity function in anisometropic myopic eyes after photorefractive keratectomy and result shows consistent outcome value. The utilization of both methods provided more accuracy in measurement of stereopsis.[24]

There are still few studies on the time on stereopsis examination, so this study's results can be used as a reference for further research. This study result may also be used as a base for future studies in stereopsis function with best corrected visual acuity (BCVA) and larger population, so stereopsis function can be evaluated across more comprehensive refractive status and various eye condition that may influence stereopsis function (e.g.strabismus, refractive amblyopia).

The limitation in this study is the refractive status is not confirmed in cycloplegic examination due to the study setting in community.

CONCLUSION

There is a significant difference of refractive status and inter-eye line difference on near stereopsis function in school-aged children. There is no significant difference on stereopsis value across age groups. Both TNO and Butterfly tests methods have a good validity in evaluating near stereopsis function. The stereopsis test may be beneficial for the screening of refractive disorder.

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