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CLINICAL STUDY

Screening amblyopia of preschool children with uncorrected vision and stereopsis tests in Eastern Taiwan

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Abstract

Aims or purpose **Screening for amblyopia at earliest age is important for early treatment and better prognosis. This study aimed at evaluating the validity of uncorrected distant and near visual acuity and random dot stereopsis for screening amblyopia.**

Methods **In Eastern Taiwan, population-based screen tests were performed for children at age from 3 to 6 years. The tests included uncorrected distant and near visions and random dot stereopsis (300 s) test. The screen performers were registered nurses of local public health service posts. The golden standards of the tests were the results of examination by the ophthalmologists.**

Results **Including Hans and aboriginal Taiwanese, 5232 children were included. Screened by distance visual acuity with different cutoffs and near visual acuity, 10.3, 30.3 and 8.2% children were abnormal. Screened by random dot, only 2% children were abnormal. By a senior ophthalmologist, 115 amblyopic children were diagnosed amblyopic. The sensitivities of distance visual acuity with low/high cutoff and near visual acuity were 74.7/84.8 and 49.4%, whereas that of the NTU random dot stereogram was 20.5%. Simultaneous testing of either two of the three tests improved the sensitivity.**

Conclusion **Screening for amblyopia by the local nurses using the visual acuity tests or random dot stereopsis test alone does not display a high sensitivity. Simultaneous testing of distant visual acuity and stereopsis test elevate the sensitivity and preserve the specificity.**

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Introduction

Amblyopia is decrease of vision in a lazy eye caused by media opacity, strabismus, anisometropia, and significant refractive errors, such as high astigmatism, hyperopia, or myopia. It is the leading cause of monocular vision loss, affecting 2–4% of the population.[1–8] A better visual prognosis in amblyopic patients is recognized if the affected eye was treated adequately in early childhood. Screening and treatment at preschool age, when it is a sensitive period of visual development, lead to a better visual outcome.[8–10] However, screening for amblyopic children is labour-intensive, costly, and sometimes unreliable.[11–14] This situation is more evident in eastern Taiwan where a mixed population of mountain aborigines and Han Taiwanese people is scattered from mountains to coasts. The screening of amblyopia in preschool children in this area has not been well reported.

Recent studies of screening amblyopia have been focused on the efficiency of using advanced diagnostic photorefractive methods, such as photoscreening. Nevertheless, traditional vision screening is still a direct and cheaper method. The latter is easier to apply when the children to be screened are sparsely scattered from mountains to seashores. Local health workers, such as nurses, have easier

access to the children and share the same dialect. However, their ability to perform such a screening has not been well examined. The children population sampled in this study included four areas from a city where Hans Taiwanese are dominant (95%) to a seashore county where aboriginals are dominant (75%).

The objective of this study was to examine the validity of screening amblyopia of preschool children performed by local health workers in Hualein of Eastern Taiwan.

Materials and methods

Population

Vision screening for amblyopia of the preschool children aged from 3 to 6 years was conducted in four areas of Hualein, eastern Taiwan, including Hualien city, Ji-an county, Shou-fong county, and Fongbin county. The population of each area was around 107, 63, 21.5, and 7.6 thousand. The proportion of aboriginals in each area was 4.7, 14.7, 24.2, and 74.4% (data from http://www.ttcsec.gov.tw/ttclearn/).
Eligible children were identified from the Public Health Posts database and an invitation to attend screening was sent to the child's parents or guardian. The methods of screening included uncorrected distance visual acuity, uncorrected near visual acuity, and random dot stereopsis test.

Definition and procedures

Children with near visual acuity in one eye or both less than 0.7 at age 3 years, 0.8 at age 4 years, 0.9 at age 5 years, and 1.0 at age 6 years were considered abnormal. Two cutoffs points of abnormal distant visual acuity were defined. The low cutoff of abnormal distance visual acuity was below 0.5 at age 3 years, 0.6 at age 4 years, 0.7 at age 5 years, and 0.8 at age 6 years. The high cutoff of abnormal distance visual acuity was below 0.7 at age 3 years, 0.8 at age 4 years, 0.9 at age 5 years, and 1.0 at age 6 years.

NTU random dot stereogram (NTU-RDS) has been widely used to screen amblyopic and strabismus children in Taiwan. The method is available at http://home.mc.ntu.edu.tw/~ahwang/NTU300-english-with-link-english.htm. Basically, it is a simple stereopsis test, using four plates, to detect a stereopsis defect worse than 300 sec-arc.

The screening was performed by registered nurses of the public health service stations in the four areas. The final examination was performed by the ophthalmologist (SMM) and their results were the gold standard against each screen test. The final eye examinations included kinetic retinoscopy, ophthalmoscopy, cover test, cover–uncover test, cycloplegic refractions, and corrected visual acuity testing of children with refractive errors or abnormal results on the above examinations.

In this study, amblyopia was defined as best corrected distant visual acuity less than 1.0. All the children were examined by the ophthalmologist (SMM) to evaluate for risk factors of amblyopia, such as high astigmatism, anisometropia, strabismus, and any other ocular abnormalities.

For each criterion, we determined sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) using standard analytical methods (Table 1).[15] Sensitivity is the probability that the screening test will be positive when an abnormality is present. Specificity indicates the probability that the screening test will be negative when an abnormality is not present. The PPV indicates the probability of an abnormality being present if the screening test is positive. The NPV indicates the probability of normality if the screening test provides a normal result.

Results

Subjects of the study

Included in this study were 5232 children with 2729 boys (52.2%) and 2503 girls (47.8%) (Table 2). Five thousand and five children (95.7%) were either in the preschool, day cares, or kindergartens, whereas 227 (4.3%) children were not attending schools. The children from the four areas were as followed: Hualien city 2803 (53.6%), Ji-an county 1722 (32.9%), Shou-fong county 548 (10.5%), and Fongbin county 159 (3%).

All the children were finally examined by the ophthalmologist (SMM). In the 5232 children, 4969 (95%) children completed distant visual acuity test; 5032 (96%) children completed near acuity test; whereas 4986 (96%) children completed random dot stereopsis. Close to 95% (4966/5232) of the children took all three of screening tests. Five thousand and seventeen (96%) children had at least two screen tests.

Table 1 Definition of analytical measures

Screening results	*Final ophthalmologists examination results (amblyopia)*	
	Abnormal	*Normal*
Abnormal	A	B
Normal	C	D

Sensitivity = A/(A + C); specificity = D/(B + D); positive predictive value = A/(A + B), negative predictive value = D/(C + D); *n* number of eyes examined = (A + B + C + D).

Table 2 Selected characteristics of participants

	Age (years)				*Total*
	3	*4*	*5*	*6*	
Boy	301 (11.0%)	730 (26.7%)	1053 (38.6%)	645 (23.6%)	2729
Girl	218 (8.7%)	702 (28.0%)	996 (39.8%)	587 (23.5%)	2503
Total	519 (9.9%)	1432 (27.4%)	2049 (39.2%)	1232 (23.5%)	5232
Attending day-care, kindergarten					
Yes	5005 (95.7%)				
No	227 (4.3%)				
Area population		N *(%)*			
Hualien City		2803 (53.6%)			
Ji-an county		1722 (32.9%)			
Shou-fong county		548 (10.5%)			
Fongbin county.		159 (3.0%)			

Rates of failing screen test

Screened by distance visual acuity with a low cutoff, 505 (10.3%) children failed to pass the test (Figure 1a), whereas screened by distance visual acuity with a high cutoff, 1490 (30.3%) children failed (Figure 1b). Screened by near visual acuity, 402 (8.2%) children failed (Figure 2). The above-mentioned proportion of children did not include those who could not perform the test, mostly too young to teach. Another 4.9% (239) children could not perform the test of distant visual acuity test. Of the 472 children at the age of 3 years who were examined with visual acuity tests, 30.3% were not capable of performing such test. However, at the age of 4 years, only 4.7% (63/1332) children could not perform the test. The percentage further decreased to 1.3% (25/1950) at the age of 5 years and 0.7% (8/1153) at the age 6 years.

Screened by NTU-RDS, only 2% (104/4980) children failed (Figure 3). Another 3.5% (174/4980) children were not capable of performing NTU-RDS. Of the 473 children at the age of 3 years who were examined with NTU-RDS, 21.4% (101/473) could not perform the test of NTU-RDS. However, at the age of 4 years, only 3.8% (51/1344) children could not perform the test. The percentage further decreased to 0.7% (14/1983) at the age of 5 years and 0.7% (8/1183) at the age 6 years.

Examined by distant visual acuity, 228 children presented unilateral visual acuity deficit, whereas by near visual acuity 176 children presented with unilateral visual acuity deficit.

Prevalence and causes of amblyopia

One hundred and fifteen amblyopic children were diagnosed amblyopia by a senior ophthalmologist (Table 3). The prevalence of the amblyopia was 2.20% (115/5232). The causes of amblyopia were strabismus 2.6% (three children), refractive errors 62.6% (72 children), anisometropia 24.3% (28 children), and organic 10.4% (12 children).

Prevalence of amblyopia in the four different areas was 2.20% of Hualein city, 2.26% of Ji-an county, 1.27% of Shou-fong county, and 0% of Fongbin county (Table 4). There is a trend of fewer amblyopic children in aborigine-dominant areas. However, there is no statistical significance (χ^2 test, $P = 0.89$).

Validity of screen tests for amblyopia

To evaluate validity of each test or simultaneous testing, we calculated their sensitivities, specificities, PPV, and NPV, as listed in Table 5. The sensitivity of NTU-RDS was low at 20.5%, whereas that of the near visual acuity was 49.4%. The best one was the distance visual acuity with high cutoff, 83.5%; however, its specificity was low at 69.0%. If the low cutoff of the distance visual acuity was adopted, the sensitivity drops to 74.7%, but the specificity improved to 90.8%. The PPV also improved from 4.5 to 12.5%.

Furthermore, we calculated the sensitivity, specificity, PPV, and NPV of the simultaneous testing of distance visual acuity, near visual acuity, and random dots. The result of simultaneously performing two tests is considered positive if either of the two tests is positive.

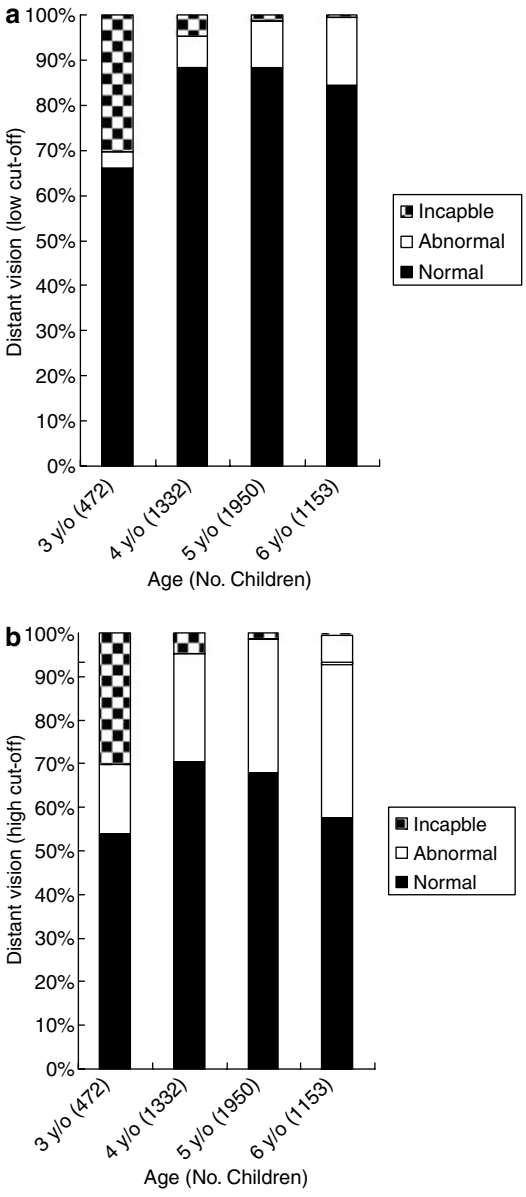

Figure 1 Performance of distance visual acuity test in different ages. (a) Low cutoff. (b) High cutoff.

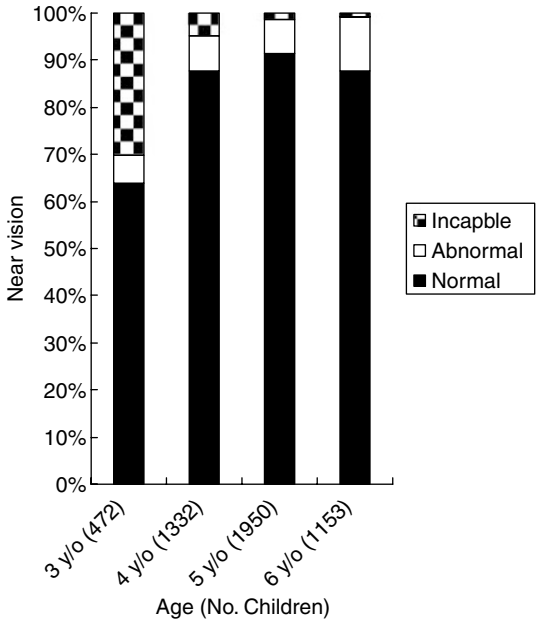

Figure 2 Performance of near visual acuity test in different ages.

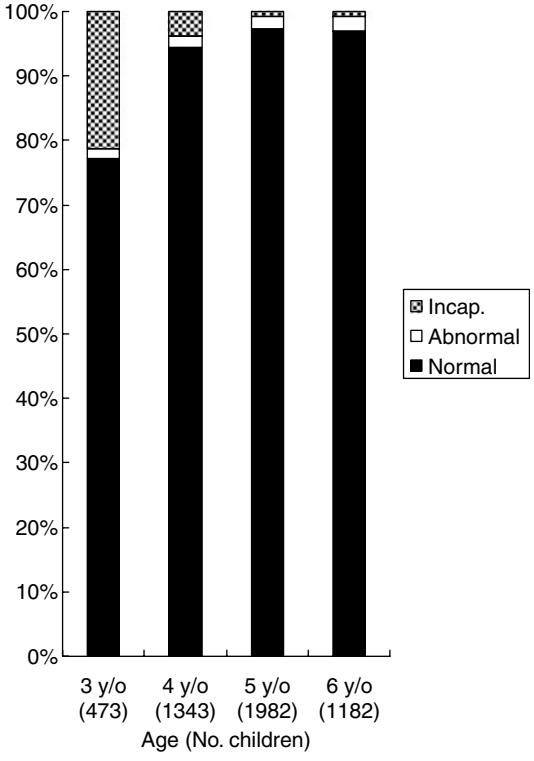

Figure 3 Performance of NTU-RDS in different ages.

Simultaneous testing with NTU-RDS and near visual acuity only improved the sensitivity to 64.5% with a specificity of 91.3% and a PPV of 12.8%. The simultaneous testing of random dot and distance visual acuity with a low cutoff increases the sensitivity to 79.3%. The specificity and PPV are 89.8 and 11.9%. In simultaneous testing with NTU-RDS and distance visual acuity with high cutoff, the sensitivity improved to 90.2% and the specificity is 68.7%, whereas the PPV is 6.1%.

The highest sensitivity was achieved by simultaneous testing of distance visual acuity (high cutoff) and near visual acuity test, 91.8%; however, its specificity and PPV are as low as 66.7 and 4.4%. Whereas, the simultaneous testing of distance visual acuity (low cutoff) and near visual acuity showed a sensitivity of 82.5%, specificity of 83.4%, and PPV of 7.9%.

Only around 11% of the amblyopia children who were unable to perform NTU test. In calculating sensitivity of NTU in detecting amblyopia, these children were excluded.

NTU-RDS and uncorrected near visual acuity

The relationship between NTU-RDS and near visual acuity was examined (Table 6). Ninety-one amblyopic children had both tests of near visual acuity and NTU-RDS successfully performed. Of these children whose near visual acuity were below 0.3, 77.8% passed NTU-RDS. With a near vision between 0.4 and 0.6, 95% children passed NTU-RDS.

Sensitivities of different screening method to detect amblyopia in each area

The sensitivity of each method except stereopsis test exhibited the highest in Ji-an county, followed by Hualien city and Shou-fong county (Table 7). Hualein city has the highest socio-economic level, followed by Ji-an county and Shou-fong county.

Discussion

The ideal screening test has high sensitivity and high specificity. However, it is not always feasible. In screening for amblyopic children, a high sensitivity is required, as we do not want to miss any children who could be treated early in their ages. Of the three tests in this study, sensitivity of detecting amblyopia varies widely, from around 20% of NTU-RDS to 85% of distant visual acuity test with high cutoff. However, the trade-off of the latter is specificity lower than 70% and PPV around 4.5%. With such a low PPV, around one-third of children requires further evaluation by the ophthalmologists. Another cost is required to transport the children in

Table 3 Causes of amblyopia

Causes	N *(%)*
Strabismus	3 (2.6)
Refractive errors	72 (62.6)
Anisometropia	28 (24.3)
Organic	12 (10.4)
Total	115

Table 4 Prevalence of amblyopia in each area

	Prevalence (numbers of screened children)
Hualein city	2.35% (2803)
Ji-an county	2.26% (1722)
Shou-fong county	1.27% (548)
Fongbin county	0% (159)
Total	2.20% (5232)

χ^2: $P = 0.89$.

Table 6 Relations of NTU-RDS and uncorrected near vision

NTU-RDS	*Near VA,* N *(%)*			
	≤0.3	*0.4–0.6*	*≥0.7*	*Total*
Normal	7 (77.8%)	19 (95.0%)	51 (82.3%)	77
Abnormal	2 (22.2%)	1 (5.0%)	11 (17.7%)	14
Total	9	20	62	91

NTU-RDS = NTU random dot stereogram; VA = visual acuity.

Table 7 Sensitivities of each area by different screening methods

	Distant VA (low) (%)	*Distant VA (high) (%)*	*Near VA (%)*	*NTU-RDS (%)*
Hualein city	72.6	78.4	52.9	22.8
Ji-an county	82.4	95.7	77.0	18.5
Shou-fong county	42.8	71.4	42.9	0
Fongbin county	NA	NA	NA	NA

NA = not available due to no case of amblyopia in that area; NTU-RDS = NTU random dot stereogram; VA = visual acuity.

Table 5 Validity of different methods of screening

	Sensitivity (%)	*Specificity (%)*	*PPV (%)*	*NPV (%)*
Distance visual acuity (low)	74.7	90.8	12.5	99.5
Distance visual acuity (high)	83.5	69.0	4.5	99.6
Near visual acuity	49.4	92.3	12.7	98.8
Random dots	20.5	98.2	17.1	98.6
Distance visual acuity (low) and near visual acuity	82.5	83.4	7.9	99.6
Distance visual acuity (high) and near visual acuity	91.8	66.7	4.4	99.7
Distance visual acuity (low) and random dot	79.3	89.8	11.9	99.4
Distance visual acuity (high) and random dot	90.2	68.7	6.1	99.7
Near visual acuity and random dot	64.5	91.3	12.8	99.2

NPV = negative predictive value; PPV = positive predictive value.

mountain areas to ophthalmologists' clinic or invite professional health workers to aboriginals' areas with all the assistants and optometric instruments. However, the children were referred not only for diagnosis and treatment of amblyopia. Refractive disorders were other main problems that account for visual deficits and were remarkable for follow-up.

The low PPV of screening for amblyopia was not caused by high number of false positive, as the specificities of most screening methods in this study were around 80–90%. Instead, low prevalence of amblyopia in the general population, around 2%, is the main cause of low PPV. Unless both sensitivity and specificity are close to 100%, PPV is not easy to be high in such a low prevalence.

Principally, simultaneous performing two tests will increase the sensitivity if either of them showing positive is considered positive. Simultaneous testing of distant visual acuity of high cutoff and other tests increase sensitivity to about 90%; nevertheless, its trade-off is specificities less than 70%. Simultaneous testing of distant visual acuity of low cutoff and other tests increases sensitivity to around 80%, whereas it reserves a specificity of 80%. Thus, the latter is a better choice to balance between sensitivity and specificity.

Visual screening for preschool children is intended not only to detect amblyopia but also to find out strabismus, which is most effectively detected by stereopsis test, and cover and uncover test. Thus, from the view of cost-effectiveness, a combination of visual acuity test and stereopsis test is more beneficial, because it increases the sensitivity to detect amblyopia and plays a role in detecting strabismus.

NTU-RDS has been widely used to screen amblyopia. However, its sensitivity was low, around 20%, in this study. The possible explanation is that mild to moderate amblyopia cannot be detected by this test when it can only detect an abnormality more than 300-s stereopsis. Around 80–95% children with near vision lower than 0.6 pass NTU-RDS. It is explicable why the sensitivity of the NTU-RDS test to screen amblyopia is low. Other stereopsis tests, such as Random Dot E stereoacuity and Stereo Smile II stereoacuity, have been noted to disclose sensitivities of 28 and 61% in detecting amblyopia.[16] Thus, stereopsis test alone is not sensitive enough to screen for amblyopia.

Theoretically, the distance visual acuity test should have a high sensitivity for amblyopic patients because these amblyopic eyes should not have uncorrected distance visual acuity better than the cutoff visions. However, in this study the sensitivity of the distance visual acuity test is around 75–85% from different cutoff points. The most possible explanation is that the examiners have not performed the test as it should have been performed and the number of false negative is therefore increased. A study from England has shown that in a test of distant visual acuity, 27% of the children had a difference of more than 2 lines between being tested by nurses and being tested by orthoptists.[12] Most of the errors came from a different distance of measuring acuity. Our study was conducted in eastern Taiwan where most of the areas are rural. The nurses in these areas might not have complete orthoptic training. Further effort should focus on training of the nurses who practice the screen tests.

To set up the standard measurement of distant visual acuity test is not always easy in different small villages of the mountain areas. Near visual acuity is a screening test easier to perform; however, its sensitivity was worse than 50% as shown in this study. Placing a pin-hole to correct refractive error in testing distant visual acuity will increase sensitivity of screening for ambyopia; however, our experience found that the children is not easily taught to see though that small hole.

The ideal screen tests should also be inexpensive, easy, and timesaving to perform both for the examiner and the children. The vision tests and the NTU-RDS are more difficult for the 3-year-old children to perform than the older children. Around 20–30% of 3-year-old children in our study were not able to perform these tests. However, the number decreases noticeably after age 3 years. Treatment of amblypia caused by refractive factors or strabismus should be started as early as possible. If 70% of 3-year-old children know how to do the test, it is still worthwhile to screen these children. With more training, the performance can be improved. In comparison with video-auto refractometer, the MTI photoscreener, or other photoscreening methods, the distance/near visual acuity test and NTU-RDS are much cheaper and easy to do. It is even more cost-effective when the latter are performed by the local health workers in the mountain aboriginal villages.

Home screening using a set of five picture cards and a questionnaire to start a stepwise screening procedure might be a cost-saving screening for visual disturbance in mountain areas.[17] However, parents in these aboriginal areas might not be capable of doing such a work.

In the setting of this study, the children including aboriginals are sparsely distributed in different areas from mountains to seaside. Local registered nurses play a very important role in such a screening work for amblyopia and the traditional vision screen method is more appropriate for them. However, they need more training in order to increase the validity of the test. From the result of this study, it has been shown that the quality of visual screening do not always exist in area of highest socio-economic area. Instead, the training and devotion of the screening performers are the key factors to elevate quality of visual screening.

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