Validity of Uncorrected Visual Acuity Measured in Vision Screening Programs for Detecting Refractive Errors

Mehdi Khabazkhoob, PhD[1] • Hassan Hashemi, MD[2] • Yadollah Mehrabi, PhD[1]
Babak Eshrati, MD, PhD[3] • Koroosh Etemad, MD, PhD[1]
Abbasali Yekta, PhD[4] • Sara Soroush, MSc[2] • Hamid Soori, PhD[5]

Abstract

***Purpose*:** Uncorrected visual acuity is the only variable measured in vision screening programs in many countries worldwide. The aim of this study was to calculate the sensitivity, specificity, and predictive value of the uncorrected visual acuity in the screening programs for the diagnosis of refractive errors.

***Methods*:** In this cross-sectional study, of 4,157 students in the first year of primary school who were selected from seven cities of Iran through multistage cluster sampling, 3,675 students participated in the study. In each school, measurement of corrected and uncorrected visual acuity, cycloplegic and non-cycloplegic refraction, and cover test were performed for all students by an optometrist. Refractive errors obtained by cycloplegic refraction were considered gold standard and the validity of uncorrected visual acuity measured in the screening program for the diagnosis of refractive error was calculated.

***Results*:** In students with visual acuity of $^{20}/_{20}$, the prevalence of myopia, hyperopia and astigmatism was 1.14%, 8.07% and 11.11%, respectively. The sensitivity of uncorrected visual acuity in the screening program for the diagnosis of myopia, hyperopia, astigmatism, and ametropia was 25.33%, 12.81%, 14.34%, and 12.64%. The area under the ROC curve of uncorrected visual acuity by optometrist and the screening program only showed a significant difference in myopia (p=0.013).

***Conclusion*:** The measurement of visual acuity in screening programs is not useful per se in the diagnosis of refractive errors and has a high percentage of false negative results. Adding refractive error examinations to the protocol of screening programs can increase their efficacy.

***Keywords*:** Vision Screening, Amblyopia, Sensitivity, Specificity, Iran

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1. Department of Epidemiology, Faculty of Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran
2. Noor Ophthalmology Research Center, Noor Eye Hospital, Tehran, Iran.
3. Department of Public Health, Arak University of Medical Sciences, Arak, Iran
4. Department of Optometry, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran
5. Safety Promotion and Injury Prevention Research Center, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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Correspondence to: *Hamid Soori, PhD*
Safety Promotion and Injury Prevention Research Center, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran, Email: hsoori@yahoo.com

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Introduction

Amblyopia is suggested as the primary cause of unilateral visual impairment in childhood and even later in life.[1-3] The diagnosis of amblyopia is the most important target of visual screening programs worldwide.[4,5] Subjective and objective tests are now performed in visual screening programs to diagnose this disorder during childhood.[6-9] Measurement of visual acuity with an E chart is a very routine examination in vision screening programs.[7,10-13] Due to the importance of vision screening, many studies have evaluated them worldwide.[13-19] Review of the literature in this area shows great variations in the sensitivity of such programs around the world. In recent years, the use of subjective methods of measuring visual acuity, like photorefraction, has increased the validity of screening programs.[20,21]

Visual screening programs are not sensitive enough and available evidence shows that in some countries like Iran, their sensitivity is even less than 50%.[13,22,23] In addition, another major weak point of screening programs in most parts of the world is the lack of refractive error examination. Refractive errors are the most prevalent cause of amblyopia[24-27] and the most common cause of visual impairment,[28] which may lead to amblyopia in children if uncorrected in childhood.

The distance E chart, which is now routinely used in visual screening programs, has a high sensitivity in detecting the cases of myopia; however, it is not sensitive enough for detecting the cases of hyperopia and astigmatism[29] although they are very prevalent in children.[30,31] On the other hand, it has been shown that if they are not corrected in childhood, they can lead to amblyopia and even strabismus. Moreover, some studies[32] have shown that hyperopia in children can decrease educational performance due to its effect on the near vision. O'Donoghue[29] from Ireland evaluated the importance of measuring refractive errors in screening programs. However, due to the importance of this issue and since there is limited evidence regarding the necessity of performing refractive errors examinations in screening programs, more extensive studies are required worldwide. It should be noticed that O'Donoghue evaluated the sensitivity of optometrist-measured visual acuity in the diagnosis of refractive errors while visual acuity is measured by people other than optometrists with less than 100% sensitivity in most screening programs worldwide.[13-15,17-19] Therefore, it is more practical and realistic to show the validity of visual acuity measured in screening programs for the diagnosis of refractive errors. Furthermore, it can also reveal the shortcomings of vision screening programs in the diagnosis of refractive errors. Due to the importance of refractive errors in children and since they are not properly assessed in vision screening programs, our study was designed and conducted to evaluate the validity of uncorrected visual acuity in the screening program (UVASP) for the diagnosis of different types of refractive errors.

Methods

This cross-sectional study was performed in 2013. In this study, the target population was the children aged 6-7-year-old who lived in urban areas of Iran. The participants were selected from the students in the first year of primary school who had received screening for visual problems.

Sampling method

In this study, seven Iranian cities from different geographic locations were randomly selected through multistage cluster sampling. In each city, in the first step, a number of boys and girls from primary schools were randomly selected in equal numbers. Then, in each school, all students in the first year were selected for sampling.

After determining the schools and coordination with the authorities of the Ministry of Education, consent forms were delivered to the schools to be completed and signed by parents.

The students entered the study based on the first letter of their family name in Persian alphabet. Moreover, demographic data such as the parents' education and occupation was extracted from the students' health profiles in the first step. Furthermore, UVASP was retrieved from the health profiles, as well. Then, the students entered the stage of optometric examination.

Examination

After the interview, the student entered the examination room and received non-cycloplegic refraction with an auto refractometer (Topcon RM8800, Topcon Corporation, Tokyo, Japan) by an experienced optometrist, and the results were recorded and attached to the student's profile. After that, the students entered the next stage. In this stage, if the student used glasses, visual acuity with current glasses was measured with an "E" Snellen chart at 6 m and the result was recorded. Then, lensometry was performed (Topcon LM 800, Topcon Corporation, Tokyo, Japan) and the power of the glasses and time of prescription was recorded. In the following step, uncorrected visual acuity was measured for all students, if uncorrected visual acuity was less than $^{20}/_{25}$ in a student, subjective refraction was performed and the results of subjective refraction with best corrected visual acuity were documented. Finally, all students received cycloplegic refraction with cyclopentolate 1%.

Definitions

According to the UK National Screening Committee,[29] we considered the specificity and sensitivity of UVASP worse than 0.2 logMAR ($^{20}/_{32}$) in the diagnosis of refractive errors. It should be mentioned that this cut point is used to refer the students to the optometrist in the screening programs in Iran, as well. Refractive errors were determined based on cycloplegic refraction similar to other studies on children. The spherical equivalent (SE) was used for calculation of refractive errors. Similar to previous studies,[33,34] myopia was defined as SE≤-0.5 D, hyperopia was defined as SE≥+2 D, and astigmatism was defined as cylinder power worse than 0.5 D. Ametropia was defined as an eye that has refractive error.

Statistical analysis

Considering the aim of the study which was to show that refractive errors are missed in vision screening programs conducted at the start of primary education, the prevalence of the refractive errors with 95% confidence interval was determined in students whose uncorrected visual acuity was reported $^{20}/_{20}$ in the screening program. Then, to determine the validity of the examinations, sensitivity, specificity, and predictive value of distance visual acuity measured in the screening program for the diagnosis of myopia, hyperopia, and astigmatism were evaluated. Moreover, Receiver Operating Curves (ROC) were used to show the best cut point in the current situation and the area under the curve was separately calculated for each refractive error. The Youden index was used to show the best cut point.

The index was suggested by Youden as a way of summarising the performance of a diagnostic test.

Results

In this study, 4,157 students were selected from seven cities in Iran of whom 3,675 students participated in the study (response rate=88.4%). 53.3% (n=1,919) of the participants were male. Cycloplegic refraction was not performed on 26 students due to contraindication or lack of cooperation; therefore, final analysis was performed on 3,649 students of whom 52.3% (n=1,907) were male. Based on the examinations in the students' health profiles, visual acuity was $^{20}/_{20}$ in 2,468 (67.6%) students.

According to the results of the present study, after regarding the weight of each city, the prevalence of myopia, hyperopia, and astigmatism was 1.14% (95%CI 0.70-1.58), 8.07% (95%CI 5.07-11.07), and 11.11% (95%CI 9.00-13.22) in students with uncorrected visual acuity $^{20}/_{20}$, respectively. In total, 18.53% (95%CI 14.94-22.13) of the students had at least one refractive error (ametropia).

Table 1 presents the results of this study with regards to refractive error based on cycloplegic refraction as gold standard and UVASP worse than 0.2 logMAR. Table 2 shows the sensitivity, specificity, predictive value, likelihood ratio, accuracy, and efficacy of the screening program for the diagnosis of refractive errors. According to Table 1, the sensitivity of UVASP worse than 0.2 logMAR for the diagnosis of myopia, hyperopia, and astigmatism was 25.33%, 12.81%, and 13.34%, respectively. Moreover, the sensitivity of this cut point was 12.64% for the diagnosis of ametropia. The highest positive likelihood ratio was seen in myopia and the lowest was seen in hyperopia. Moreover, according to table 2, the highest

positive predictive value was for astigmatism and the lowest was for myopia.

The accuracy of UVASP worse than 0.2 logMAR for the diagnosis of myopia, hyperopia, astigmatism, and at least one refractive error was 93.58%, 87.11%, 83.37%, and 76.76%, respectively. Figure 1 depict the ROC curve of UVASP and uncorrected visual acuity measured by the optometrist for the diagnosis of each refractive error separately.

Table 3 presents the area under the ROC curve of UVASP and uncorrected visual acuity measured by the optometrist for detecting different types of refractive errors. For all refractive errors, the area under the ROC curve was significantly different from 0.5 ($p<0.001$). Moreover, comparison of the area under the curve of UVASP and uncorrected visual acuity by optometrist (UVAO) showed a significant difference only in myopic patients ($p=0.013$).

Table 2 demonstrates the sensitivity, specificity, and likelihood ratioof different cut points of UVASP for detecting myopia, hyperopia, astigmatism, and ametropia. Moreover, according to the maximum of Yuden index, a cut point of equal to or worse than 0.18 LogMAR for uncorrected visual acuity has the best sensitivity and specificity for the diagnosis of myopia in the screening program. The results of Yuden index showed that this cut point was 0.05 logMAR for astigmatism and hyperopia.

Table 1. Validity of uncorrected visual acuity cut-off of poorer 0.2 logMAR ($^{20}/_{32}$) to diagnosis myopia, hyperopia, astigmatism and ametropia

	Myopia		Hyperopia		Astigmatism		Ametropia	
	%	95%CI	%	95%CI	%	95%CI	%	95%CI
Sensitivity	25.33	15.99 to 36.70	12.81	9.56 to 16.66	14.34	11.57 to 17.48	12.64	10.51 to 15.04
Specificity	95.01	94.25 to 95.70	95.42	94.65 to 96.11	96.23	95.49 to 96.87	96.86	96.15 to 97.48
Likelihood Ratio+	5.08	3.36 to 7.69	2.80	2.05 to 3.81	3.80	2.90 to 4.97	4.03	3.08 to 5.29
Likelihood Ratio-	0.79	0.69 to 0.90	0.91	0.88 to 0.95	0.89	0.86 to 0.92	0.9	0.88 to 0.93
Predictive Value	9.64	5.91 to 14.65	23.86	18.07 to 30.45	41.41	34.46 to 48.63	55.84	48.59 to 62.91
Predictive Value	98.38	97.90 to 98.77	90.72	89.70 to 91.67	85.79	84.58 to 86.94	77.96	76.54 to 79.33

Likelihood Ratio is not percentage

Table 2. Sensitivity, specificity, likelihood ratio and Youden's index of uncorrected visual acuity based on different cut pointsfor the diagnosis of myopia, hyperopia, astigmatism and ametropia

UCVA (logMAR)	Myopia					Hyperopia				
	Sensitivity (%)	Specificity (%)	YI	LR+	LR-	Sensitivity (%)	Specificity (%)	YI	LR+	LR-
≥0.05	64.21	68.49	32.70	2.04	0.52	46.83	68.86	15.69	1.5	0.77
≥0.1	62.11	71.44	33.55	2.17	0.53	42.96	71.71	14.67	1.52	0.8
≥0.18	43.16	92.77	35.93	5.97	0.61	19.37	92.78	12.15	2.68	0.87
≥0.2	22.11	96.54	18.65	6.39	0.81	12.32	96.76	9.08	3.8	0.91
≥0.3	13.68	97.16	10.84	4.82	0.89	10.21	97.47	7.68	4.04	0.92
≥0.4	7.37	97.66	5.03	3.16	0.95	9.15	98.1	7.25	4.81	0.93
≥0.48	7.37	97.92	5.29	3.54	0.95	7.39	98.22	5.61	4.15	0.94
≥0.6	1.05	98.59	-0.36	0.75	1	4.58	98.87	3.45	4.05	0.97
≥0.7	0	99.94	-0.06	0	1	0.35	99.97	0.32	11.85	1
UCVA (logMAR)	**Astigmatism**					**Ametropia**				
	Sensitivity (%)	Specificity (%)	YI	LR+	LR-	Sensitivity (%)	Specificity (%)	YI	LR+	LR-
≥0.05	53.05	72.17	25.22	1.91	0.65	49.16	73.04	22.2	1.82	0.7
≥0.1	49.54	74.97	24.51	1.98	0.67	45.33	75.69	21.02	1.86	0.72
≥0.18	21.95	94.85	16.8	4.27	0.82	19.57	95.51	15.08	4.36	0.84
≥0.2	10.98	97.59	8.57	4.56	0.91	10.24	98.08	8.32	5.33	0.92
≥0.3	7.77	97.9	5.67	3.69	0.94	7.42	98.26	5.68	4.27	0.94
≥0.4	5.64	98.23	3.87	3.19	0.96	5.51	98.51	4.02	3.71	0.96
≥0.48	4.88	98.36	3.24	2.98	0.97	4.72	98.59	3.31	3.34	0.97
≥0.6	1.98	98.73	0.71	1.56	0.99	2.36	98.91	1.27	2.17	0.99
≥0.7	0.3	100	0.3	1		0.22	100	0.22	1	

UCVA: Uncorrected visual acuity, LR: Likelihood ratio, YI: Youden's index

Table 3. ROC area: use of uncorrected visual acuity to detect type of refractive errors

		ROC area (95%CI)	p
Myopia	Uncorrected visual acuity by optometrist	0.717 (0.658-0.776)	0.013
	Uncorrected visual acuity by screening program	0.801 (0.75-0.853)	
Hyperopia	Uncorrected visual acuity by optometrist	0.596 (0.562-0.629)	0.477
	Uncorrected visual acuity by screening program	0.608 (0.58-0.637)	
Astigmatism	Uncorrected visual acuity by optometrist	0.646 (0.623-0.669)	0.096
	Uncorrected visual acuity by screening program	0.667 (0.646-0.687)	
Ametropia	Uncorrected visual acuity by optometrist	0.629 (0.608-0.649)	0.050
	Uncorrected visual acuity by screening program	0.650 (0.633-0.667)	

Ametropia: An eye that has refractive error is said to have ametropia or be ametropic.

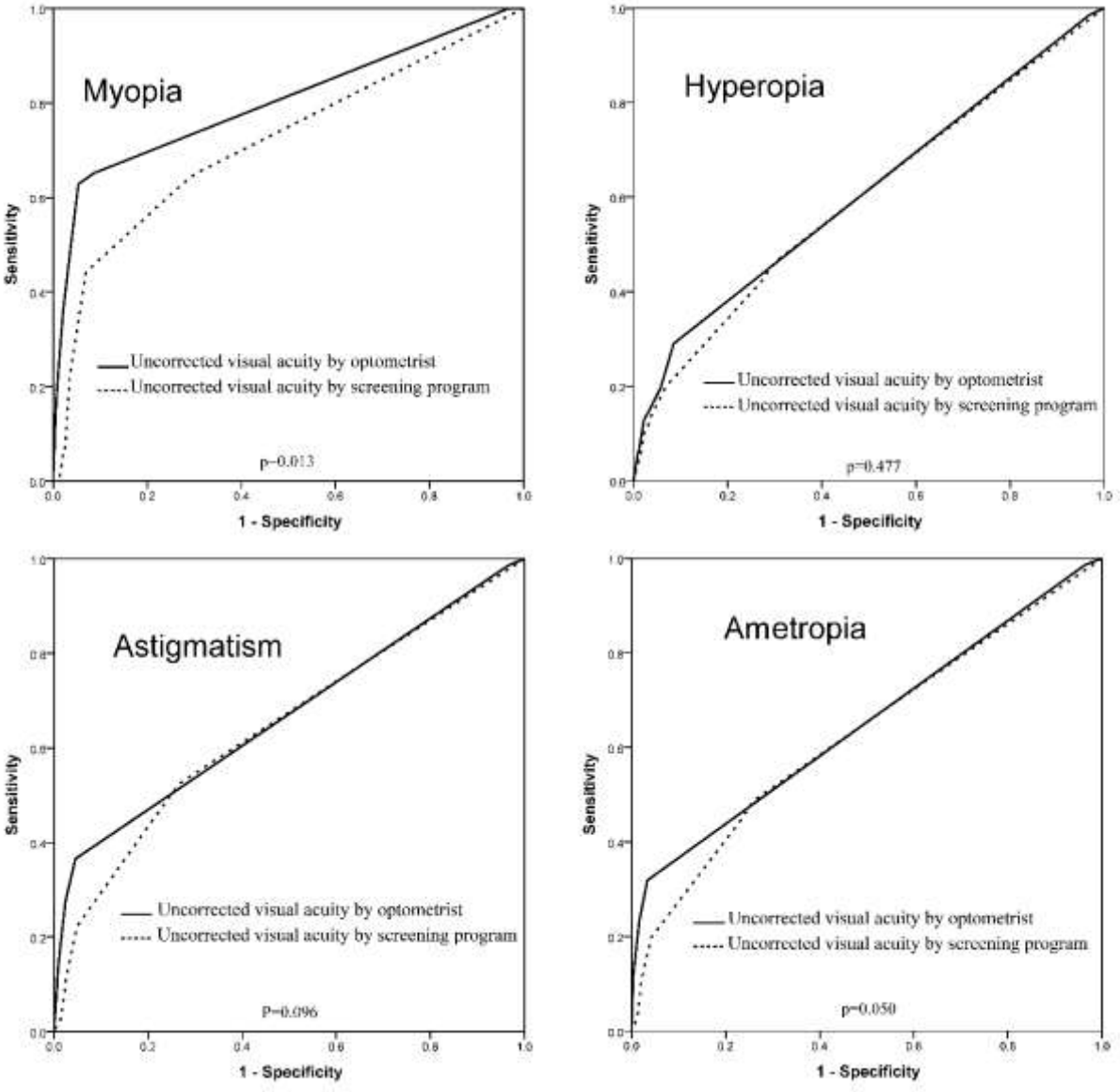

Figure 1. Roc curve: use of uncorrected visual acuity (logMAR) by screening program to detect myopia, hyperopia, astigmatism and ametropia

Discussion

As mentioned earlier, the aim of the present study was to show the importance of refractive error examination in vision screening of the students of the first year of primary school. We used two methods to show the importance of refractive error examination to achieve this objective. In the first method, we evaluated refractive errors in students who had a uncorrected visual acuity of $^{20}/_{20}$ in vision screening and showed the percentage of refractive errors which was missed in these individuals. In the second method, we assessed the validity of UVASP in detecting each refractive error. A limited number of studies have evaluated the importance of visual acuity measurement in detecting refractive errors.[29,35,36] However, since they used visual acuity by optometrist, it seems that their results do not represent actual situations since screening programs are performed by people other than optometrists in most countries.[17,23]

As mentioned in the results, of students who had visual acuity $^{20}/_{20}$ and were not referred for further evaluation, 18.53% had ametropia, 1.14% had myopia, 11.11% had astigmatism, and 8.07% had hyperopia. Although the prevalence of myopia was lower than hyperopia and astigmatism, it should be noticed that the prevalence of myopia in less than other refractive errors in children.[30,31] Moreover, since distant visual acuity of $^{20}/_{20}$ was used to detect myopia, vision screening programs are expected to detect a high percentage of cases with myopia[37] while according to table 1, the sensitivity of distant visual acuity measured in the vision screening programs for the diagnosis of myopia was about 25%. In other words, 75% of the myopic students cannot be detected in vision screening programs. In comparison, other studies have reported the reliability of distant visual acuity in detecting myopia.[36,37] For example, Leone et al[36] reported that the sensitivity of distant vision screening for detecting myopia was more than 97% in Australian children aged 12 years old. O'Donoghue et al[29] reported that the sensitivity of distant visual acuity in detecting myopia was 92% in Irish children aged 12-13 years old. This finding shows that distant visual acuity measurement by non-optometrists in the vision screening program in Iran has a low sensitivity.

However, the difference can be partly due to the different age groups of the participants between our study and the study performed by O'Donoghue.[29] Since the mean age of the participants was higher in the study by O'Donoghue,[29] and their responses were more accurate.

This finding is clearly demonstrated in figure 1 in which the ROC curve shows that the area under the curve for visual acuity by optometrist is significantly more than the area under the curve of the visual acuity measured in the screening program. Regardless of the validity of visual acuity in detecting myopia, this finding suggests that visual acuity by optometrist is more valid. One of the reasons for the apparent difference between the findings of our study and other investigations[29,36] is the person in charge of measuring visual acuity.

The results of our study showed that about 8% of students with visual acuity of $^{20}/_{20}$ were hyperopic. Since distant vision is good in hyperopic people with the use of accommodation and their near vision is impaired, this finding was expected. Hyperopia is very prevalent in childhood but part of it is compensated with accommodation.[30,31,38] According to the definition of hyperopia, SE more than 2 D was considered hyperopia according to cycloplegic refraction. In other words, the cases that were defined as hyperopic in this study were clinically important even after the compensation of accommodation.

It should be noticed that hyperopic people have more difficulties and problems with near activity than myopic individuals and they suffered symptoms like headache as a result of prolonged accommodation at the time of the study. Moreover, hyperopic children are prone to amblyopia.[39] However, our study showed that the sensitivity of visual acuity measured in the screening program for detecting hyperopia was 13%. The sensitivity percentage was 70% and 89% in studies conducted by Leone et al[36] and O'Donoghue et al,[29] respectively. It seems that one of the reasons for the high sensitivity in the diagnosis of hyperopia in the study performed by o'Donoghue et al[29] is the definition they

used for hyperopia (as SE more than 3.5 D); therefore, most of the hyperopic cases had severe hyperopia which could affect distant vision, as well.

Regarding astigmatism, since the sensitivity of detecting astigmatism was more than hyperopia in our study, about 11% of the students with visual acuity $^{20}/_{20}$ had astigmatism. Astigmatism can affect daily activities, specially studying. Moreover, undetected and untreated cases of astigmatism can result in amblyopia in children. Therefore, attention to hyperopia and astigmatism in screening programs and treatment and follow-up of the affected people can improve their vision, their education performance, and even their psychological profile. However, the important point regarding hyperopia and astigmatism is that we expect to miss a certain percent of the cases of hyperopia and astigmatism when diagnosis is based on distant visual acuity while comparison of the percentage of false negative between our study and other investigations showed that in addition to the low validity of the measurement method, the validity of the examiner was also low. According to the studies by O'Donoghue et al[29] and Leone et al,[36] distant visual acuity is of no use in detecting hyperopia and astigmatism and is only useful in detecting the cases of myopia while our study showed different results even for myopia.

Moreover, the results of the ROC curve analysis and the area under the curve showed that visual acuity measured has a low validity for detecting hyperopia and astigmatism, regardless of the examiner (optometrist or non-optometrist). The area under the ROC curve was very similar in astigmatic and hyperopic patients with no significant difference. Furthermore, the area under the curve was small in both methods, suggesting that the measurement of visual acuity alone has low validity in detecting astigmatism and hyperopia, regardless of the examiner.

Conclusion

In conclusion based on our findings, we suggest that cycloplegic refraction should be added to the vision screening program. Although inexpensive tests are routinely used in screening programs, attention should be paid to the sensitivity and predictive value of the screening programs. If cycloplegic refraction cannot be performed for any reason, near visual acuity can be used in vision screening to detect non-myopic cases.

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References

1. Foran S, Wang JJ, Mitchell P. Causes of visual impairment in two older population cross-sections: the Blue Mountains Eye Study. Ophthalmic Epidemiol 2003;10(4):215-25.
2. Simons K. Amblyopia characterization, treatment, and prophylaxis. Surv Ophthalmol 2005;50(2):123-66.
3. Tarczy-Hornoch K, Cotter SA, Borchert M, McKean-Cowdin R, Lin J, Wen G, et al. Prevalence and causes of visual impairment in Asian and non-Hispanic white preschool children: Multi-ethnic Pediatric Eye Disease Study. Ophthalmology 2013;120(6):1220-6.
4. Fu J, Li SM, Li JL, Li SY, Liu LR, Wang Y, et al. Screening for amblyopia among grade-1 students in primary school with uncorrected vision and stereopsis test in central China. Chin Med J (Engl) 2013;126(5):903-8.
5. Speeg-Schatz C, Lobstein Y, Burget M, Berra O, Riehl C, Hoffmann C. A review of preschool vision screening for strabismus and amblyopia in France: 23 years experience in the Alsace region. Binocul Vis Strabismus Q 2004;19(3):151-8.
6. Arnold RW, Arnold AW, Stark L, Arnold KK, Leman R, Armitage MD. Amblyopia detection by camera: Gateway to portable, inexpensive vision screening (calibration and validation of inexpensive, pocket-sized photoscreeners). Alaska Med 2004;46(3):63-72.
7. Chang CH, Tsai RK, Sheu MM. Screening amblyopia of preschool children with uncorrected vision and stereopsis tests in Eastern Taiwan. Eye (Lond) 2007;21(12):1482-8.
8. Donahue SP. Objective vision screening for amblyopia in children: a test that has finally arrived. Ophthalmology 2010;117(10):1867-8.
9. Schlenker MB, Christakis TJ, Braga-Mele RM. Comparing a traditional single optotype visual acuity test with a computer-based visual acuity test for childhood amblyopia vision screening: a pilot study. Can J Ophthalmol 2010;45(4):368-74.
10. Chaplin PK, Bradford GE. A historical review of distance vision screening eye charts: what to toss, what to keep, and what to replace. NASN Sch Nurse 2011;26(4):221-8.

11. Kemper AR, Helfrich A, Talbot J, Patel N, Crews JE. Improving the rate of preschool vision screening: an interrupted time-series analysis. Pediatrics 2011;128(5):e1279-84.
12. Lai YH, Hsu HT, Wang HZ, Chang SJ, Wu WC. The visual status of children ages 3 to 6 years in the vision screening program in Taiwan. J AAPOS 2009;13(1):58-62.
13. OstadiMoghaddam H, Fotouhi A, Hashemi H, Yekta A, Heravian J, Ghalandarabadi M, et al. Validity of vision screening tests by teachers among school children in Mashhad, Iran. Ophthalmic Epidemiol 2012;19(3):166-71.
14. Chui L, Fraser T, Hoar K, LaRoche GR. Negative predictive value of a vision screening program aimed at children aged 3 to 4 years old. J AAPOS 2004;8(6):566-70.
15. Dahlmann-Noor AH, Vrotsou K, Kostakis V, Brown J, Heath J, Iron A, et al. Vision screening in children by Plusoptix Vision Screener compared with gold-standard orthoptic assessment. Br J Ophthalmol 2009;93(3):342-5.
16. Khandekar R, Al Harby S, Abdulmajeed T, Helmi SA, Shuaili IS. Validity of vision screening by school nurses in seven regions of Oman. East Mediterr Health J 2004;10(4-5):528-36.
17. Khandekar R, Parast N, Arabi A. Evaluation of 'vision screening' program for three to six-year-old children in the Republic of Iran. Indian J Ophthalmol 2009;57(6):437-42.
18. Lang D, Leman R, Arnold AW, Arnold RW. Validated portable pediatric vision screening in the Alaska Bush. A VIPS-like study in the Koyukon. Alaska Med 2007;49(1):2-15.
19. Nielsen LS, Skov L, Jensen H. Vision screening in children with developmental delay can be improved: analysis of a screening programme outside the ophthalmic clinic. Dev Med Child Neurol 2007;49(7):508-12.
20. McCurry TC, Lawrence LM, Wilson ME, Mayo L. The plusoptiX S08 photoscreener as a vision screening tool for children with autism. J AAPOS 2013;17(4):374-7.
21. Nathan NR, Donahue SP. Modification of Plusoptix referral criteria to enhance sensitivity and specificity during pediatric vision screening. J AAPOS 2011;15(6):551-5.
22. Tengtrisorn S, Singha P, Chuprapawan C. Prevalence of abnormal vision in one-year-old Thai children, based on a prospective cohort study of Thai children (PCTC). J Med Assoc Thai 2005;88 Suppl 9:S114-20.
23. Vision in Preschoolers Study Group. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the vision in preschoolers study. Invest Ophthalmol Vis Sci 2005;46(8):2639-48.
24. Brown SA, Weih LM, Fu CL, Dimitrov P, Taylor HR, McCarty CA. Prevalence of amblyopia and associated refractive errors in an adult population in Victoria, Australia. Ophthalmic Epidemiol 2000;7(4):249-58.
25. Chia A, Dirani M, Chan YH, Gazzard G, Au Eong KG, Selvaraj P, et al. Prevalence of amblyopia and strabismus in young singaporean chinese children. Invest Ophthalmol Vis Sci 2010;51(7):3411-7.
26. Multi-ethnic Pediatric Eye Disease Study Group. Prevalence of amblyopia and strabismus in African American and Hispanic children ages 6 to 72 months the multi-ethnic pediatric eye disease study. Ophthalmology 2008;115(7):1229-36.
27. Sapkota K, Pirouzian A, Matta NS. Prevalence of amblyopia and patterns of refractive error in the amblyopic children of a tertiary eye care center of Nepal. Nepal J Ophthalmol 2013;5(9):38-44.
28. Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. Br J Ophthalmol 2012;96(5):614-8.
29. O'Donoghue L, Rudnicka AR, McClelland JF, Logan NS, Saunders KJ. Visual acuity measures do not reliably detect childhood refractive error--an epidemiological study. PLoS One 2012;7(3):e34441.
30. Giordano L, Friedman DS, Repka MX, Katz J, Ibironke J, Hawes P, et al. Prevalence of refractive error among preschool children in an urban population: the Baltimore Pediatric Eye Disease Study. Ophthalmology 2009;116(4):739-46.
31. Lan W, Zhao F, Lin L, Li Z, Zeng J, Yang Z, et al. Refractive errors in 3-6 year-old Chinese children: a very low prevalence of myopia? PLoS One 2013;8(10):e78003.
32. Williams WR, Latif AH, Hannington L, Watkins DR. Hyperopia and educational attainment in a primary school cohort. Arch Dis Child 2005;90(2):150-3.
33. Yekta A, Fotouhi A, Hashemi H, Dehghani C, Ostadimoghaddam H, Heravian J, et al. Prevalence of refractive errors among schoolchildren in Shiraz, Iran. Clin Experiment Ophthalmol 2010;38(3):242-8.
34. Maul E, Barroso S, Munoz SR, Sperduto RD, Ellwein LB. Refractive Error Study in Children: results from La Florida, Chile. Am J Ophthalmol 2000;129(4):445-54.
35. Fotouhi A, KhabazKhoob M, Hashemi H, Yekta AA, Mohammad K. Importance of including refractive error tests in school children's vision screening. Arch Iran Med 2011;14(4):250-3.
36. Leone JF, Mitchell P, Morgan IG, Kifley A, Rose KA. Use of visual acuity to screen for significant refractive errors in adolescents: is it reliable? Arch Ophthalmol 2010;128(7):894-9.
37. Tong L, Saw SM, Tan D, Chia KS, Chan WY, Carkeet A, et al. Sensitivity and specificity of visual acuity screening for refractive errors in school children. Optom Vis Sci 2002;79(10):650-7.
38. Tarczy-Hornoch K. The epidemiology of early childhood hyperopia. Optom Vis Sci 2007;84(2):115-23.
39. Klimek DL, Cruz OA, Scott WE, Davitt BV. Isoametropic amblyopia due to high hyperopia in children. J AAPOS 2004;8(4):310-3.