SENSITIVITY AND SPECIFICITY IN METHODS FOR EXAMINATION OF OCULAR ASTIGMATISM

SUMMARY

Purpose: We usually use objective and subjective methods for examination of the eye astigmatism in optometry, respectively ophthalmology. Objective methods enable to measure sphere-cylindrical refraction of the eye. If we want to prescribe new glasses or contact lenses we usually use subjective methods. The aim of this study was to measure sensitivity and specificity of some subjective and objective methods for examination of the eye astigmatism. We supposed that automatic objective refraction will be the most exact method so we choose this method as the reference method. For comparison we chose subjective methods Jackson crossed cylinders (JCC), fogging method (FM) and objective method Spot Vision Screener (SVS, Welch Allyn).

Materials and methods: We had in total 30 subjects with average age 23 years (SD 1 year) in our study. We made each measurement per eye separately and it was independent measurement so we could use measurement from each eye (n = 60). Each eye was firstly measured by subjective method FM, followed by JCC method and finally was use objective method Spot Vision Screener (SVS, Welch Allyn). Measurement with objective instrument TRK-1P (TOPCON) was use as reference measurement. The significance level was set at $p = 0.05$.

Results: In variable FM we measured sensitivity 76.2 % and specificity 66.7 %. Criterion for positive finding was -0.25 D. Result was statistically significant on level $p < 0.001$. In variable JCC we measured sensitivity 95.2 % and specificity 66.7 %. Criterion for positive finding was -0.25 D. Result was statistically significant on level $p < 0.001$. In variable SVS we measured sensitivity 47.6 % and specificity 94.4 %. Criterion for positive finding was -0.75 D. Result was statistically significant on level $p < 0.001$. Direct comparison of all methods showed statistically important difference between techniques JCC and FM ($p = 0.0095$). In other method we did not find statistically important difference (FM vs. SVS, $p = 0.526$ and JCC vs. SVS, $p = 0.105$).

Conclusion: All subjective and objective techniques were statistically significant in detection of eye astigmatism. Comparison of ROC curves showed statistically significant difference between FM and JCC technique. The JCC method showed the highest sensitivity, whereas SVS highest specificity.

Key words: Subjective refraction, objective refraction, sensitivity, specificity, Jackson crossed cylinder, fogging method

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INTRODUCTION

In optometry and ophthalmology we use both objective and subjective methods for the measurement and correction of ocular astigmatism. Objective methods enable detection of the precise spherical-cylindrical refraction of the eye. However, for determining the prescription for glasses or selecting suitable contact lenses, subjective values of ocular refraction are used. The reason is mainly the subjective comfort of the examined patient with the given correction. This comfort is determined by the monocular and binocular aspects of glasses correction. Among the monocular aspects we may include for example non-colour defects of image formation such as astigmatism of

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broad beams and connected arching of the visual field. Binocular aspects of glasses correction include mainly anisometropia and the resulting aniseikonia. In general patients tolerate a difference in vertex refractivity in glasses lenses of up to 3 D [2].

In practice the examination of the refractive condition of the eye usually begins with an objective measurement, which is quick and together with habitual correction demonstrates how the final subjective refraction of the eye might appear. There then follows one of the subjective techniques, which begin monocularly and end with final binocular correction. By this method, comfortable final binocular subjective refraction is determined, on the basis of which it is possible to produce glasses correction or after adjustment select suitable diagnostic contact lenses.

The majority of refractive errors occurring in the population constitute a combination of short- or long-sightedness with astigmatism. The presence of ocular astigmatism has a negative impact on visual acuity. In general we can state that we select correction of astigmatism in adult individuals in the case that it has a positive influence on visual acuity. In child patients, correction of astigmatism is selected wherever it is present, meaning detected by an objective method [2].

A number of methods exist for objective examination of refraction of the eye. At present the most widely used techniques are automatic refractometers. These are most frequently based on the measurement of defocusing of a test sign and the use of an infrared ray in order not to influence accommodation of the eye. More modern refractometers work on the principle of a Shack-Hartmann sensor, and in glasses correction enable the measurement to take into account also higher order aberrations of the eye [4].

The most widely used techniques for subjective determination of astigmatism include the method known as Jackson crossed cylinders. This technique enables the measurement to attain the values detected by an objective method with a high degree of precision (usually to 5° and 0.25 D). The second most commonly used technique for examination of ametropia including astigmatism of the eye is the fogging method, which is very quick and irreplaceable especially in patients with hypermetropia and astigmatism. This represents a situation in which patients need to disable accommodation non-pharmacologically. We can accomplish this easily upon prepending a strong converging lens [2].

The aim of our study was to verify the values of sensitivity and specificity in subjective and objective methods for evaluating ocular astigmatism, especially their screening potential and usability in practice. We assumed that objective refraction with the aid of an automatic refractometer (TRK-1P, Topcon Deutschland Medical GmbH) would provide valid information about the presence or absence of ocular astigmatism, primarily thanks to the technological possibilities of this instrument, in which we may include for example high repeatability of measurement [7,9]. For this reason we chose this method as the classification variable. Among other variables we included the subjective fogging method, the method of Jackson crossed cylinders and the objective method of the portable automatic refractometer Spot Vision Screener (Welch Allyn GmbH, Germany).

METHOD

In our study we had a total of 30 probands with a mean age of 23 years (SD 1 year). The cohort comprised 28 women and 2 men. At the moment of testing the eyes did not manifest any ocular pathologies.

The measurement was conducted on each eye separately, and we mutually compared measurements always from one eye. We were thus able to include a total of 60 eyes in our cohort. Each eye was measured first of all by the subjective fogging method (FM) for measuring ocular astigmatism, there followed the technique of Jackson crossed cylinders (JCC), then an objective method with the aid of the portable refractometer Spot Vision Screener (SVS), and the last measurement was performed on the automatic refractometer TRK-1P (ARM). The above sequence of four measurements on the given eye was always performed by the same examiner. Each measuring sequence of one pair of eyes was then performed by a different examiner. For the purposes of further processing, the values of spherical-cylindrical correction determined were always uniformly converted to a record with a negative value of the cylinder.

For our study we used statistical tests for the evaluation of sensitivity and specificity. We considered measurement with the aid of the automatic refractometer TRK-1P as a classification variable. We also had the following variables available: FM (fogging method), JCC (Jackson crossed cylinders) and SVS (automatic refractometer Spot Vision Screener).

The resulting value of sensitivity expressed in percentages shows the ability of the test to detect an eye with astigmatism. On the other hand, the specificity in our study demonstrates the ability of the test to detect an eye without astigmatism. The correct values of both variables always relate to the selected discrimination criterion. The expected optimal values in both cases should approach 100%. The used statistical tests should demonstrate whether the aforementioned methods are sensitive and specific on a statistically significant level. For analysis a so-called ROC (Receiver Operating Characteristic) curve was used, illustrating the mutual dependency of sensitivity and 1 – specificity. We evaluated the classification legitimacy of the individual methods with the aid of the surface beneath the ROC curve (AUC – Area Under Curve). A comparison of the individual methods was conducted on the basis of testing a zero hypothesis on the equality of the areas under the corresponding ROC curves. The optimum value of the discrimination criterion for each studied method was determined by means of computer software, and presupposed a record of correction with a negative cylinder.

The results of measurement were converted into an MS Excel table and subsequently statistically evaluated with the aid of the statistical program Statistica version 12 from the company STATSOFT and MedCalc. The statistical level of significance was selected as p = 0.05.

RESULTS

In the first subjective test for examining refraction by the fogging method we used a statistical analysis of ROC curves to attain these values. The criterion for detecting positive individuals was equal to or less than -0.25 D. The corresponding sensitivity value was 76.2%, the specificity value was 66.7%. The result (AUC = 0.75) was statistically significant on a level of significance $p < 0.001$ (Graph 1 and Table 1). The mean value of measured astigmatism was -0.30 D (SD = 0.30 D).

Following a statistical evaluation, the second subjective test for examining refraction, Jackson crossed cylinders demonstrated a sensitivity value of 95.2% and specificity of 66.7%. In this the relevant criterion for detecting positive individuals was the same as in the previous test, i.e. equal to or less than -0.25 D. The result (AUC = 0.892) was statistically significant on a level of significance of $p < 0.001$ (Graph 1 and Table 1). The mean value of determined astigmatism was -0.35 D (SD = 0.27 D).

The third test was an objective examination of refraction with the aid of the portable automatic refractometer Spot Vision Screener. In this case the value for detecting positive individuals was less than or equal to -0.75 D. The statistical evaluation in this test demonstrated the lowest sensitivity value of 47.6%, but the highest specificity value of 94.4%. The result (AUC = 0.801) was statistically significant on a level of significance of < 0.001 (Graph 1 and Table 1). The mean measured value of astigmatism was -0.50 D (SD = 0.32 D).

A direct comparison of all three above-mentioned methods demonstrated a statistically significant difference in sensitivity and specificity (p = 0.0095) between the FM and JCC tests. In the other tests the evaluated difference were not statistically significant (FM v SVS, p = 0.526 and JCC v SVS, p = 0.105), as can also be seen from the course of the curves in graph 1 (Table 2).

The mean value of astigmatism measured by the refractive technique ARM was -0.30 D (SD = 0.30). A total of 43 eyes had a positive astigmatic finding. The mean value of astigmatism in these selected eyes was 0.48 D (SD = 0.30).

DISCUSSION

Evaluation of sensitivity and specificity in optometry is used for example in predicting refractive errors in children. In the study by Tonga et al. [8], by means of an analysis of the ROC curve the authors determined a value of visual acuity of 0.28 logMAR as the optimal discrimination criterion for the prediction of a refractive error in a child. In this case the sensitivity of a modified ETDRS test for examination of visual acuity was 72%, with specificity of 97%, in a sample of children of school age in Singapore.

It is also possible to use sensitivity and specificity for an evaluation of the validity of electronic tests for measuring visual acuity. These tests are very quick and enable patients to determine through self-examination whether they have a refractive error. Thanks to the study by Hashemi et al. [3], we know that it is possible to predict only myopia statistically significantly (p = 0.013) with the aid of these electronic tests. In a cohort of 4157 students, myopia was detected in 25.33% thanks to this electronic test. By contrast, hypermetropia was detected only in 12.81%.

Another important tool for evaluating binocular defects (in particular for demonstrating amblyopia) in children is “photoscreening”. This examination can be performed also on the smallest children (< 3 years). Visual photoscreening can be performed, for example in Great Britain, also by persons who do not have professional qualification. It is usually performed with the aid of portable autorefractometers (e.g. PowerRefractor, Plusoptix, iScreen, Spot Vision Screener etc.). Thanks to the study by Sanchez et al. [7] we know that the sensitivity and specificity of these instruments attains relatively high values. For example, in the case of the Plusoptix instrument, sensitivity as high as 99% and specificity of 82% has been measured. In general it is possible to detect early amblyopia, high refractive error, undercorrected hypermetropia or overcorrected myopia with the aid of these instruments. In these cases, however, the studies focus mainly on the diagnosis of hypermetropia and myopia.

In our study we used sensitivity and specificity for demonstrating astigmatism in adult patients. In clinical practice various techniques are used for examining ocular astigmatism. The ideal technique will be quick, but at the same time precise and will not place a burden either

Graph 1. Comparison of ROC curves obtained for individual used methods (FM – fogging method, JCC – Jackson crossed cylinders, SVS – Spot Vision Screener)

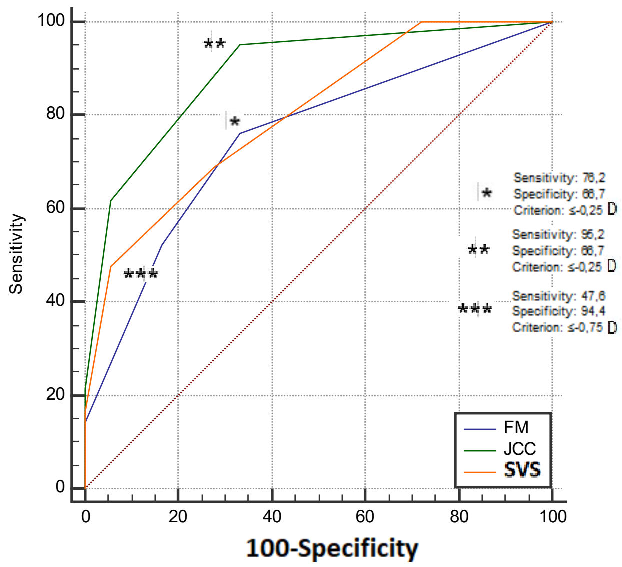

Table 1. Statistical evaluation of sensitivity and specificity in studied methods (FM – fogging method, JCC – Jackson crossed cylinders, SVS – Spot Vision Screener)

Variable	FM	JCC	SVS
Area under ROC curve (AUC)	0.75	0.892	0.801
Standard error	0.063	0.0418	0.056
95% reliability interval	0.621-0.853	0.785-0.958	0.678-0.893
Z statistic	3.967	9.379	5.369
Level of significance P (Surface = 0.5)	0.0001	< 0.0001	< 0.0001

Table 2. Mutual statistical comparison of used methods on the basis of ROC curves (FM – fogging method, JCC – Jackson crossed cylinders, SVS – Spot Vision Screener)

Variable	FM - JCC	FM - SVS	JCC - SVS
Differences between surfaces	0.142	0.0509	0.0913
Standard error	0.0549	0.0803	0.0564
95% reliability interval	0.0347-0.250	-0.106-0.208	-0.0192-0.202
Z statistic	2.592	0.624	1.619
Level of significance P (Surface = 0.5)	0.0095	0.526	0.1054

on the examiner or the patient. In optometric practice, the technique of Jackson crossed cylinders figures in first place. The method of second choice is the fogging technique for determining ocular astigmatism. These techniques are complex and meet the above-stated requirements. In our study we determined that all the objective and subjective techniques we used are usable and suitable for demonstrating ocular astigmatism on a statistically significant level. We measured the highest sensitivity in a subjective test of Jackson crossed cylinders (95.2%). The highest specificity was demonstrated by the instrument Spot Vision Screener (94.4%), which is used as an objective technique for photoscreening in children with a defect of development of binocular vision.

In the professional literature [5] the issue of inter- and intra-personal repeatability of the test is also frequently analysed. In our case this problem (subjective intra-personal influence) was suppressed by the fact that each sequence of measurements (FM-JCC-SVS) was performed by a different person. The methods were compared mutually among themselves.

The autorefractometer (ARM) method was chosen as the referential technique due to its objectivity and large degree of repeatability within the framework of measurement. The instrument recorded 5 measurements, which it averaged. The discrimination criteria of the individual subjective methods (JCC = 0.25 D, FM = 0.25 D) demonstrated that these techniques have a substantial capability of detecting even low astigmatism.

CONCLUSION

In our study we evaluated the sensitivity and specificity of subjective methods for examining ocular astigmatism. This concerned the fogging method and the method of Jackson crossed cylinders. The FM method demonstrated sensitivity of 76.2% and specificity of 66.7%. In addition we evaluated an objective technique with the aid of the portable refractometer Spot Vision Screener. Here the value of sensitivity was 47.6% and specificity 94.4%. The automatic refractometer TRK-1P secured the referential values.

Upon a comparison of the ROC curves we determined that a statistically significant difference exists between the FM and JCC methods, especially in the value of sensitivity. On the basis of the obtained results we can therefore state that with the aid of the JCC subjective refractive method we are able to perform the identification and correction of ocular astigmatism with a high level of reliability. On the other hand, in the case of the objective method (SVS), we are able with a high level of reliability to exclude patients in whom ocular astigmatism is absent.

LITERATURE

1. **Allen, PM., O´Leary, DJ.:** Accommodation functions: Co-dependency and relationship to refractive error. Vision Research, 46; 2006: 491-505.
2. **Anton, M.:** Refrakční vady a jejich vyšetřovací metody. 3. vydání, NCONZO, 2004.
3. **Hashemi, H., Yekta, A., Jafarzadehpur, E. et al.:** Sensitivity and specificity of preschool vision screening in Iran. Iran J Public Health, 46; 2017: 207-215.

4. **Marcos, S., Diaz-Santana, L., Llorente, L., et al.**: Ocular aberrations with ray tracing and Shack–Hartmann wave-front sensors: Does polarization play a role? J. Opt. Soc. Am, 19; 2002: 1063-1072.
5. **Mohan, KM., Miller, JM., Dobson, V., et al.:** Inter-rater and intra-rater reliability in the interpretation of MTI Photoscreener photographs of Native American preschool children. Optom Vis Sci, 77; 2000: 473–482.
6. **Rozsíval, P. a kol.:** Oční lékařství. Praha, Galén, 2006, 363 s.
7. **Sanchez, I., Ortiz-Toquero, S., Martin, R. et al.:** Advantages, limitations, and diagnostic accuracy of photoscreeners in early detection of amblyopia: a review. Clin Opththalmol, 10; 2016: 1365-1373.
8. **Tong, L., Saw, SM., Tan, D.:** Sensitivity and specificity of visual acuity screening for refractive errors in school children. Optom Vis Sci, 79; 2002: 650-7.
9. **Walline, JJ., Kinney, KA., Zadnik, K., et al.:** Repeatability and validity of astigmatism measurements. J Refract Surg, 15; 1999: 23-31.